Regional Haze State Implementation Plan

For
Kentucky's Class I Area

Prepared by

Kentucky Energy and Environment Cabinet

Kentucky Division for Air Quality

Final

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Preface: This document contains summaries of the technical analyses that will be used by the Kentucky Division for Air Quality (KYDAQ) to support the regional haze State Implementation Plan (SIP) pursuant to §§107(d)(3)(D) and (E) of the Clean Air Act, as amended. KRS 224.10-100(5) provides the Kentucky Energy and Environment Cabinet (formerly the Environmental and Public Protection Cabinet) with the statutory authority to adopt and implement its regional haze SIP. A link to KRS 224.10-100 is as follows:
http://www.lrc.ky.gov/KRS/224-10/100.PDF.

EXECUTIVE SUMMARY

Introduction

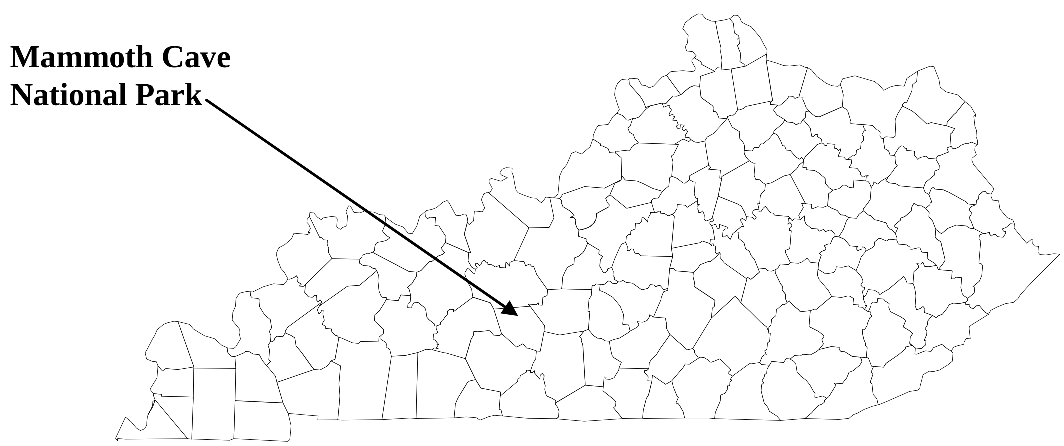
Regional haze is pollution that impairs visibility over a large region, including national parks, forests, and wilderness areas (many termed "Class I" areas). Regional haze is caused by sources and activities emitting fine particles and their precursors, often transported over large regions. Particles affect visibility through the scattering and absorption of light. Reducing fine particles in the atmosphere is an effective method of improving visibility. In the southeast, the most important sources of haze-forming emissions are coal-fired power plants, industrial boilers and other combustion sources, but also include mobile source emissions, area sources, fires, and wind blown dust.

An easily understood measure of visibility to most people is visual range. Visual range is the greatest distance, in kilometers or miles, at which a dark object can be viewed against the sky. However, the most useful measure of visibility impairment is light extinction, which affects the clarity and color of objects being viewed. The measure used by the regional haze rule is the deciview (dv), calculated directly from light extinction using a logarithmic scale.

The regional haze rule requires states to demonstrate reasonable progress toward meeting the national goal of a return to natural visibility conditions by 2064. The rule directs states to graphically show what would be a "uniform rate of progress," also known as the "glide path," toward natural conditions for each Class I area within the State and certain ones outside the State.

Kentucky's Class I Area

Kentucky has one Class I area within its borders: Mammoth Cave National Park. The figure below illustrates the location of Mammoth Cave in Kentucky.



Visibility on the worst days at Mammoth Cave is an estimated 31dv. Natural background visibility on the worst days is an estimated 11 dv.

State Implementation Plan Requirements

States are required to submit state implementation plans (SIPs) to the United States Environmental Protection Agency that set out each state's plan for meeting the national goal of a return to natural visibility conditions by 2064. The plan includes the states' reasonable progress goals, expressed in deciviews, for visibility improvement at each affected Class I area for each 10-year period until 2064.

SIPs must include determinations of the baseline visibility conditions (expressed in deciviews) for the most impaired and least impaired days. In addition, states must include a monitoring strategy for measuring, characterizing, and reporting of regional haze visibility impairment. The long-term strategy includes enforceable emissions limitations, compliance schedules, and other measures as necessary to achieve the reasonable progress goals. States must also consider ongoing control programs, measures to mitigate construction activities, source retirement and replacement schedules, smoke management programs for agriculture and forestry, and enforceability of specific measures.

The SIPs for the first review period are due December 17, 2007. These plans will cover long-term strategies for visibility improvement between baseline conditions in 2000-2004 and 2018. States are required to evaluate progress toward reasonable progress goals every 5 years to ensure that installed emissions controls are on track with emission reduction forecasts in each SIP.

Federal and State Control Requirements

There are significant control programs being implemented between the baseline period and 2018. These programs will all reduce the particulate emissions that affect visibility in the Class I areas, and include: the Clean Air Interstate Rule (CAIR), the NO_x SIP Call or state equivalent, one-hour ozone SIPs submitted by Atlanta, Birmingham, and Northern Kentucky, NOx RACT in 8-hour nonattainment area SIPs, heavy duty diesel (2007) engine standard (for on-road trucks and buses), Tier 2 tailpipe standards for on-road vehicles, large spark ignition and recreational vehicle rule, nonroad diesel rule, and various Federal Maximum Achievable Control Technology regulations and consent agreements with Tampa Electric, Virginia Electric and Power Company, Gulf Power, East Kentucky Power Cooperative, American Electric Power and the PM2.5 attainment demonstrations due in April 2008.

The regional haze rule also requires states to determine best available retrofit technology (BART) for certain facilities. Twenty-one of Kentucky's twenty-six BART-eligible sources were able to demonstrate that they did not cause or contribute to visibility impairment. Further BART determination analysis of five Kentucky Electric Generating Units (EGUs) provided for the installation of controls to reduce visibility impairing emissions.

Conclusion

For Kentucky's Class I area, Mammoth Cave National Park, visibility improvements on the worst days are expected to be better than the uniform rate of progress glidepath by 2018 based solely on reductions from existing and planned emissions controls. Additionally, the visibility is expected to improve for the best days at Mammoth Cave. The table below displays the 2018 reasonable progress goals for Kentucky's Class I area.

Class I Area	Baseline Visibility for Worst Days (dv)	Uniform Rate of Progress for Worst Days (dv)	Reasonable Progress Goal Modeled for Worst Days (dv)	Baseline Visibility for Best Days (dv)	Uniform Rate of Progress for Best Days (dv)	Reasonable Progress Goal Modeled for Best Days (dv)
Mammoth Cave National Park, KY	31.37	26.64	25.56	16.51	16.51	15.57

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1.0 INTRODUCTION

1.1 What is regional haze?

Regional haze is pollution from disparate sources that impairs visibility over a large region, including national parks, forests, and wilderness areas (156 of which are termed mandatory Federal "Class I" areas). Regional haze is caused by sources and activities emitting fine particles and their precursors. Those emissions are often transported over large regions.

Particles affect visibility through the scattering and absorption of light, and fine particles – particles similar in size to the wavelength of light – are most efficient, per unit of mass, at reducing visibility. Fine particles may either be emitted directly or formed from emissions of precursors, the most important of which are sulfur dioxides (SO2) and nitrogen oxides (NOx). Reducing fine particles in the atmosphere is generally considered to be an effective method of reducing regional haze, and thus improving visibility. Fine particles also adversely impact human health, especially respiratory and cardiovascular systems. The United States Environmental Protection Agency (USEPA) has set national ambient air quality standards for daily and annual levels of fine particles with diameter smaller than 2.5 μm (PM2.5). In the southeast, the most important sources of PM2.5 and its precursors are coal-fired power plants, industrial boilers and other combustion sources. Other significant contributors to PM2.5 and visibility impairment include mobile source emissions, area sources, fires, and wind blown dust.

1.2 What are the requirements under the Clean Air Act for addressing regional haze?

In Section 169A of the 1977 Amendments to the Clean Air Act (CAA), Congress set forth a program, for protecting visibility in Class I areas, which calls for the "prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I Federal areas which impairment results from manmade air pollution." Congress adopted the visibility provisions to protect visibility in these 156 national parks, forests and wilderness areas. On December 2, 1980, the USEPA promulgated regulations to address visibility impairment (45 FR 80084). The 1980 regulations were developed to address visibility impairment that is "reasonably attributable" to a single source or small group of sources. These regulations represented the first phase in addressing visibility impairment and deferred action on regional haze that emanates from a variety of sources until monitoring, modeling and scientific knowledge about the relationships between pollutants and visibility impairment improved.

In the 1990 Amendments to the CAA, Congress added section 169B and called on the USEPA to issue regional haze rules. The regional haze rule that the USEPA promulgated on July 1, 1999 (64 FR 35713), revised the existing visibility regulations in order to integrate provisions addressing regional haze impairment and establish a comprehensive visibility protection program for Class I Federal areas. States are required to submit state implementation plans (SIPs) to the USEPA that set out each states' plan for complying with the regional haze rule, including consultation and coordination with other states and with Federal Land Managers (FLMs). The timing of SIP submittal is tied to the USEPA's promulgation of designations for the National Ambient Air Quality Standard (NAAQS) for fine particulate matter. States must submit a regional haze implementation plan to the USEPA within three years after the date of designation. Because the USEPA promulgated designation dates on December 17, 2004, regional haze SIPs must be submitted by December 17, 2007.

The regional haze rule addressed the combined visibility effects of various pollution sources over a wide geographic region. This wide reaching pollution net meant that many states – even those without Class I areas – would be required to participate in haze reduction efforts. The USEPA designated five Regional Planning Organizations (RPOs) to assist with the coordination and cooperation needed to address the visibility issue. The RPO that makes up the southeastern portion of the contiguous United States is known as VISTAS (Visibility Improvement – State and Tribal Association of the Southeast), and includes the eastern band of the Cherokee Indians in addition to the following states: Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia.

Figure 1.2-1. Geographical Areas of Regional Planning Organizations

1.3 General overview of regional haze SIP requirements

The regional haze rule at 40 CFR 51.308(d) requires states to demonstrate reasonable progress toward meeting the national goal of a return to natural visibility conditions by 2064. As a guide for reasonable progress, the regional haze rule directs states to graphically show what would be a "uniform rate of progress" toward natural conditions for each mandatory Class I Federal area within the State and/or for each mandatory Class I Federal area located outside the State, which may be affected by emissions from sources within the State. States are to establish baseline visibility conditions for 2000-2004, natural background visibility conditions in 2064, and the rate of uniform progress between baseline and background conditions. The uniform rate of progress is also known as the "glidepath."

The regional haze rule then requires states to establish reasonable progress goals, expressed in deciviews, for visibility improvement at each affected Class I area covering each (approximately) 10-year period until 2064. The goals must provide for reasonable progress towards achieving natural visibility conditions, provide for improvement in visibility for the most impaired days over the period of the implementation plan, and ensure no degradation in visibility for the least impaired days over the same period (see 40 CFR 51.308(d)(1)).

In order to ensure that visibility goals are properly met and set, state plans must include determinations, for each Class I area, of the baseline visibility conditions (expressed in deciviews) for the most impaired and least impaired days. SIPs must also contain supporting documentation for all required analyses used to calculate the degree of visibility impairment under natural visibility conditions for the most impaired and least impaired days (see 40 CFR 51.308(d)(2)). In addition, states must include a monitoring strategy for measuring, characterizing, and reporting of regional haze visibility impairment that is representative of all mandatory Class I Federal areas within the state (see 40 CFR 51.308(d)(4)).

This first set of reasonable progress goals must be met through measures contained in the state's long-term strategy covering the period from the present until 2018. The long-term strategy includes enforceable emissions limitations, compliance schedules, and other measures as necessary to achieve the reasonable progress goals, including all controls required or expected under all federal and state regulations by 2009 and by 2018. During development of the long-term strategy, states are also required to consider specific factors such as the above mentioned ongoing control programs, measures to mitigate construction activities, source retirement and replacement schedules, smoke management programs for agriculture and forestry, and enforceability of specific measures (see 40 CFR 51.308(d)(3)).

In addition, a specific component of each state's first long-term strategy is dictated by the specific best available retrofit technology (BART) requirements in 40 CFR 51.308(e) of the regional haze rule. The regional haze rule at 40 CFR 51.308(e) requires states to include a determination of BART for each BART-eligible source in the State that emits any air pollutant, which may reasonably be anticipated to cause or contribute to any impairment of visibility in any mandatory Class I Federal area. The Clean Air Act section 169A(b) defines BART-eligible sources as sources in 26 specific source categories, in operation within a 15-year period prior to enactment of the 1977 Clean Air Act Amendments and having total potential emissions of 250 tons per year or more for any visibility-impairing pollutant for all emission units. States must determine BART according to five factors set out in section 169A(g)(7) of the Clean Air Act. Emission limitations representing BART and schedules for compliance with BART for each source subject to BART must be included in the long-term strategy.

The SIPs for the first review period are due December 17, 2007. These plans will cover long-term strategies for visibility improvement between baseline conditions in 2000-2004 and 2018. States are required to evaluate progress toward reasonable progress goals every 5 years to ensure that installed emissions controls are on track with emissions reduction forecasts in each SIP. The first interim review will be due to the USEPA in December 2012. If emissions controls are not on track to meet SIP forecasts, then states would need to take action to ensure emissions controls by 2018 will be consistent with the SIP or to revise the SIP to be consistent with the revised emissions forecast.

The USEPA provided several guidance documents listed below to assist the states in implementation of the regional haze rule requirements. KYDAQ followed these guidance documents in developing the technical analyses reported in this plan.

- Guidance for Tracking Progress Under the Regional Haze Rule (EPA-454/B-03-004, September 2003).
- Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Rule (EPA-454/B-03-005, September 2003).
- Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5 and Regional Haze (EPA, 2007).
- Guidance for Setting Reasonable Progress Goals Under the Regional Haze Program (EPA, June 2007).

1.4 Class I area in Kentucky

Kentucky has one Class I area within its borders: Mammoth Cave National Park. The Kentucky Energy and Environment Cabinet's Division for Air Quality (KYDAQ) is responsible for developing the Kentucky's Regional Haze SIP. This SIP establishes reasonable progress goals for visibility improvement at its Class I area, and a long-term strategy that will achieve those reasonable progress goals within the first regional haze planning period.

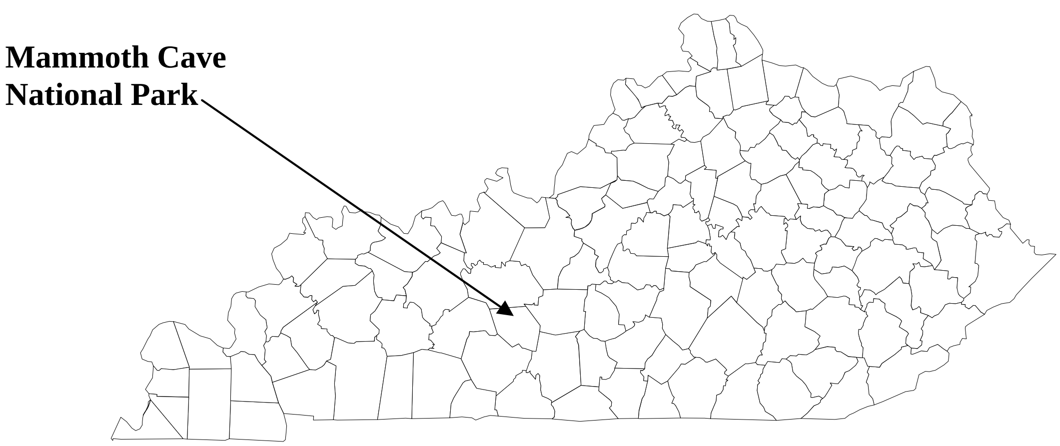


Figure 1.4-1. Kentucky Class I area

In developing this SIP, the KYDAQ has also considered that emission sources outside of Kentucky may affect visibility at Kentucky's Class I area, and that emission sources within Kentucky may affect visibility at Class I areas in neighboring states. Through VISTAS, the southeastern states have worked together to assess state-by-state contributions to visibility impairment in specific Class I areas, including Mammoth Cave in Kentucky and those affected by emissions from Kentucky. This technical work is discussed further in Sections 5, 6, and 7. Consultations to date between Kentucky and other states are summarized in Section 10; consultations are ongoing.

Prior to VISTAS, the southern states cooperated in a voluntary regional partnership to identify and recommend reasonable measures to remedy existing and prevent future adverse effects from human-induced air pollution on the air quality related values of the Southern Appalachian Mountains. States cooperated with the FLMs, the USEPA, industry, environmental organizations and academia to complete a technical assessment of the impacts of acid deposition, ozone, and fine particles on sensitive resources in the Southern Appalachians. The (Southern Appalachian Mountain Initiative) SAMI Final Report was delivered in August 2002. The SAMI Assessment concluded that ammonium sulfate is the major contributor to visibility impairment in the Southern Appalachian Mountains and to improve visibility, it is most important to reduce SO2 emissions. SAMI also concluded that reducing ammonia emissions would be helpful to reduce ammonium nitrate contributions to visibility impairment. Emissions controls for organic carbon, elemental carbon, and soil were expected to be less important for improving visibility. The SAMI modeling found that on the haziest days, much of the benefit of emissions reductions would occur in the state where emissions reductions were made. Emissions in surrounding SAMI states and states outside the SAMI region also contribute to air quality in the SAMI Class I areas. The SAMI states supported strong national multi-pollutant legislation to accomplish its mission. Emissions reductions to meet national health standards for ozone and fine particles were expected to also improve air quality in the Southern Appalachian Mountains. The SAMI states committed to consider air quality benefits in the Southern Appalachians as they developed SIPs for the health standards.

Congress considered several legislative bills to reduce SO2 and NOx from electric generating utilities. In 2004, the USEPA promulgated the Clean Air Interstate Rule (CAIR) to require emissions reductions for SO2 and NOx from electric generating utilities in 26 eastern states. The CAIR rule allows for interstate trading of emissions to find cost-effective reductions. These reductions will improve visibility in the Class I area in Kentucky.

1.5 State and Federal Land Manager (FLM) coordination

As required by 40 CFR §51.308(i), the regional haze SIP must include procedures for continuing consultation between the States and FLMs on the implementation of the visibility protection program, including development and review of implementation plan revisions and 5-year progress reports, and on the implementation of other programs having the potential to contribute to impairment of visibility in any mandatory Class I Federal area within the State. The three FLMs are the United States Department of Interior's (USDI's) Fish and Wildlife Service (FWS) and National Park Service (NPS) and the United States Department of Agriculture's (USDA's) Forest Service (FS).

Successful implementation of a regional haze program will involve long-term regional coordination among states. VISTAS was formed in 2001 to address regional haze and visibility problems in the southeastern United States. Jurisdictions represented by VISTAS members include the Eastern Band of Cherokee Indians; the States of Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia; and the local air pollution control programs located in these States. A copy of the VISTAS Memorandum of Agreement and Bylaws is enclosed as Appendix A.

The objectives of the VISTAS project are to establish natural background visibility conditions across the mandatory Class I Federal areas, identify current visibility impairment levels, analyze emission control levels that will achieve interim visibility goals, and provide adequate documentation to member agencies so that they can develop their regional haze State/Tribal Implementation Plans (SIP/TIP). Figure 1.5-1 shows the 18 mandatory Class I Federal areas in the VISTAS Region, where visibility is an important value. Table 1.5-1 lists these Class I areas and the reported acreage associated with the Class I areas.

Figure 1.5-1. Class I Areas in the VISTAS Region

Table 1.5-1 Mandatory Class I Federal Areas in the VISTAS Region

State	Area Name	Acreage	Federal Land Manager
Alabama	Sipsey Wilderness	24,922	USDA-FS
Florida	Chassahowitzka Wilderness	23,579	USDI-FWS
	Everglades National Park	1,397,429	USDI-NPS
	St. Marks Wilderness	17,350	USDI-FWS
Georgia	Cohutta Wilderness	36,977	USDA-FS
	Okefenokee Wilderness	353,981	USDI-FWS
	Wolf Island Wilderness	5,126	USDI-FWS
Kentucky	Mammoth Cave National Park	51,303	USDI-NPS
North Carolina	Great Smoky Mountains National Park	273,551	USDI-NPS
	Joyce Kilmer-Slickrock Wilderness	13,562	USDA-FS
	Linville Gorge Wilderness	11,786	USDA-FS
	Shining Rock Wilderness	18,483	USDA-FS
	Swanquarter Wilderness	8,785	USDI-FWS
South Carolina	Cape Romain Wilderness	29,000	USDI-FWS
Tennessee	Great Smoky Mountains National Park	241,207	USDI-NPS
	Joyce Kilmer-Slickrock Wilderness	3,832	USDA-FS
Virginia	James River Face Wilderness	8,886	USDA-FS
	Shenandoah National Park	190,535	USDI-NPS
West Virginia	Dolly Sods Wilderness	10,215	USDA-FS
	Otter Creek Wilderness	20,000	USDA-FS

2.0 ASSESSMENT OF BASELINE AND CURRENT CONDITIONS AND ESTIMATE OF NATURAL BACKGROUND CONDITIONS IN CLASS I AREAS

The goal of the Regional Haze Rule is to restore natural visibility conditions to the 156 Class I areas identified in the 1977 Clean Air Act Amendments. 40 CFR 51.301(q) defines natural conditions: "Natural conditions include naturally occurring phenomena that reduce visibility as measured in terms of light extinction, visual range, contrast, or coloration." The Regional Haze SIPs must contain measures that make "reasonable progress" toward this goal by reducing anthropogenic emissions that cause haze.

An easily understood measure of visibility to most people is visual range. Visual range is the greatest distance, in kilometers or miles, at which a dark object can be viewed against the sky.

For evaluating the relative contributions of pollutants to visibility impairment, however, the most useful measure of visibility impairment is light extinction, which is usually expressed in units of inverse megameters (Mm^{-1}). Light extinction affects the clarity and color of objects being viewed.

The measure used by the regional haze rule is the deciview (dv). Deciviews are calculated directly from light extinction using a logarithmic scale. The deciview is a useful measure for tracking progress in improving visibility, because each deciview change is an equal incremental change in visibility perceived by the human eye. Most people can detect a change in visibility at one deciview.

For each Class I area, there are three metrics of visibility that are part of the determination of reasonable progress:

1) natural conditions,
2) baseline conditions, and
3) current conditions.

Each of the three metrics includes the concentration data of the visibility pollutants as different terms in the light extinction algorithm, with respective extinction coefficients and relative humidity factors. Total light extinction when converted to deciviews (dv) is calculated for the average of the 20 percent best and 20 percent worst visibility days.

“Natural” visibility is determined by estimating the natural concentrations of visibility pollutants and then calculating total light extinction. “Baseline” visibility is the starting point for the improvement of visibility conditions. It is the average of the Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring data for 2000 through 2004 and is equivalent to “current” visibility conditions for this initial review period. The comparison of initial baseline conditions to natural visibility conditions indicates the amount of improvement necessary to attain natural visibility by 2064. Each state must estimate natural visibility levels for Class I areas within its borders in consultation with Federal Land Managers and other states (40 CFR 51.308(d)(2)). “Current conditions” are assessed every five years as part of the SIP review where actual progress in reducing visibility impairment is compared to the reductions committed to in the SIP.

2.1 Estimating Natural Conditions for Kentucky’s Class I Area

Natural background visibility, as defined in *Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program*, EPA-454/B-03-005, September 2003, is based on annual average concentrations of fine particle components. The same annual average natural background visibility is assumed for all Class I areas in the eastern United States (separate values are estimated for the western United States). Natural background visibility for the 20 percent worst days is estimated by assuming that fine particle concentrations for natural background are normally distributed and the 90^{th} percentile of the annual distribution represents natural background visibility on the 20 percent worst days.

In the 2003 guidance, USEPA also provided that states may use a "refined approach" to estimate the values that characterize the natural visibility conditions of the Class I areas. The purpose of such a refinement would be to provide more accurate estimates with changes to the extinction algorithm that may include the concentration values, factors to calculate extinction from a measured particular species and particle size, the extinction coefficients for certain compounds, geographical variation (by altitude) of a fixed value, and the addition of visibility pollutants.

In 2005 the IMPROVE Steering Committee made recommendations for a refined equation that modifies the terms of the original equation to account for the most recent data. The choice between use of the old or the new equation for calculating the visibility metrics for each Class I area is made by the state in which the Class I area is located.

The new IMPROVE equation accounts for the effect of particle size distribution on light extinction efficiency of sulfate, nitrate, and organic carbon. The mass multiplier for organic carbon (particulate organic matter) is increased from 1.4 to 1.8. New terms are added to the equation to account for light extinction by sea salt and light absorption by gaseous nitrogen dioxide. Site-specific values are used for Rayleigh scattering to account for the site-specific effects of elevation and temperature. Separate relative humidity enhancement factors are used for small and large size distributions of ammonium sulfate and ammonium nitrate and for sea salt. The elemental carbon (light-absorbing carbon), fine soil, and coarse mass terms do not change between the original and new IMPROVE equation.

Natural background conditions using the new IMPROVE equation are calculated separately for each Class I area. The calculation starts with the annual average values for natural background for each component of PM2.5 mass from the EPA 2003 guidance (default values). The annual frequency distribution of values of each PM2.5 component for current conditions (2000-2004) is then defined. This species-specific frequency distribution is applied to the default annual average values for that PM2.5 component to calculate natural conditions on the 20% worst days. The current variability in each component is retained while also retaining the same annual average background condition for that component as defined in the 2003 guidance. The new calculation of natural background allows Rayleigh scattering to vary with elevation. Current sea salt values are used for natural background levels of sea salt.

The VISTAS states chose to use the new IMPROVE equation as the basis for the conceptual description because it takes into account the most recent review of the science and because it is recommended by the IMPROVE Steering Committee. For more detailed discussion of the two IMPROVE equations, see Appendix B.

2.2 Estimating Baseline Conditions for Kentucky's Class I Area

Baseline visibility conditions at Kentucky's Class I area is estimated using sampling data collected at the IMPROVE monitoring site at Mammoth Cave National Park. A five year average (2000 to 2004) was calculated for each of the 20 percent worst and 20 percent best visibility days in accordance with 40 CFR 51.308(d)(2) and *Guidance for Tracking Progress Under the Regional Haze Rule*, EPA-454-03-004, September 2003. IMPROVE data records for Mammoth

Cave for the period 2000 to 2004 meet USEPA requirements for data completeness (75 percent for the year and 50 percent for each quarter). The light extinction and deciview visibility values for the 20 percent worst and 20 percent best visibility days at Mammoth Cave are based on data and calculations included in Appendix B of this SIP.

2.3 Summary of Natural Background and Baseline Conditions for Kentucky's Class I Area

Table 2.3-1 presents estimated natural background and baseline visibility metrics for Kentucky's Class I area. Note that Kentucky is not considering international emissions to be a component of natural background. Baseline visibility on the 20 percent worst days at the Mammoth Cave monitoring site is predicted to be 31 dv. Natural background visibility at the Mammoth Cave monitoring site is predicted to be 11 dv. A list of the 20 percent worst and 20 percent best days used in the technical analyses for Kentucky's Class I area are available on page 7 of Appendix F.2.

Table 2.3-1 Natural Background and Baseline Conditions for Kentucky's Class I Area

Natural Background Conditions				
Class I area	**Average for 20 percent Worst Days (deciviews)**	**Average for 20 percent Best Days (deciviews)**	**Average for 20 percent Worst Days Bext (Mm-1)**	**Average for 20 percent Best Days Bext (Mm-1)**
Mammoth Cave	**11.1**	**5.0**	**30.7**	**16.5**
Baseline Visibility Conditions 2000-2004				
Class I area	**Average for 20 percent Worst Days (deciviews)**	**Average for 20 percent Best Days (deciviews)**	**Bext (Mm-1) Average for 20 percent Worst Days**	**Bext (Mm-1) Average for 20 percent Best Days**
Mammoth Cave	**31.4**	**16.5**	**241.4**	**53.0**

2.4 Pollutant Contributions to Visibility Impairment (2000-2004 Baseline Data)

The 20 percent worst visibility days at Kentucky's Mammoth Cave generally occur in the period March through September. The peak hazy days occur in the summer under stagnant weather conditions with high relative humidity, high temperatures, and low wind speeds. The 20 percent best visibility days at Mammoth Cave generally can occur at any time of year. Figures 2.4-1 and 2.4-2 display the average light extinction for the 20% haziest days and 20% clearest days, respectively.

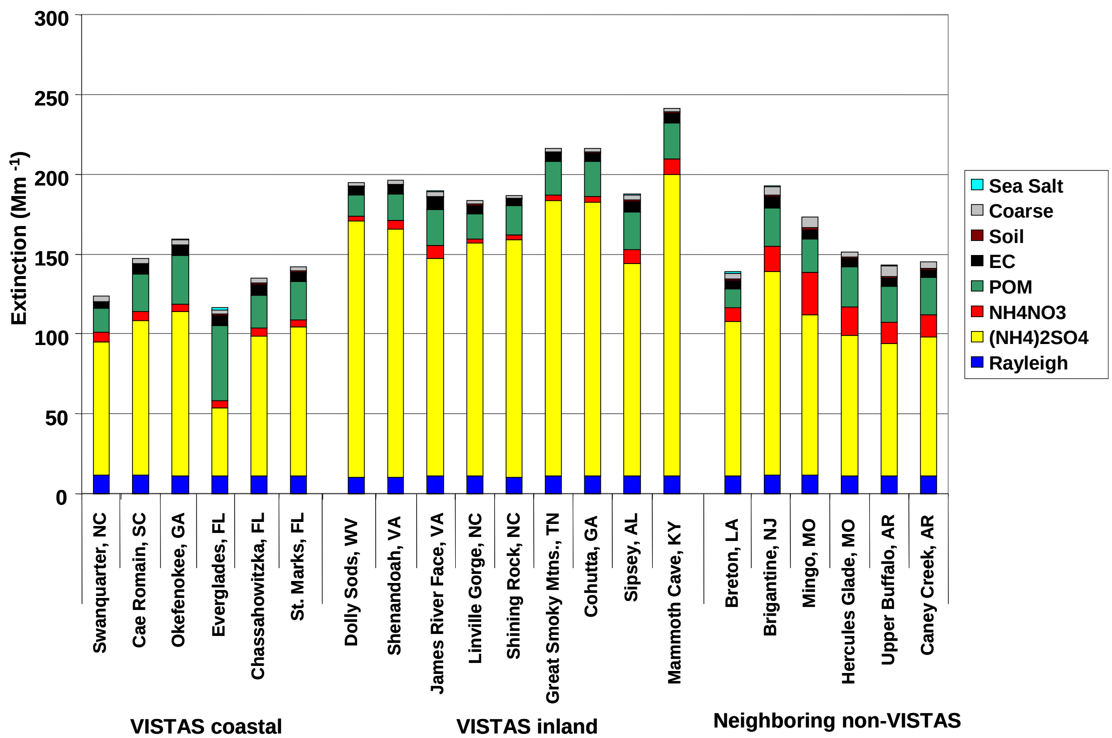


Figure 2.4-1. Average light extinction for the 20 percent Haziest Days in 2000-2004 at VISTAS and neighboring Class I areas using New IMPROVE equation

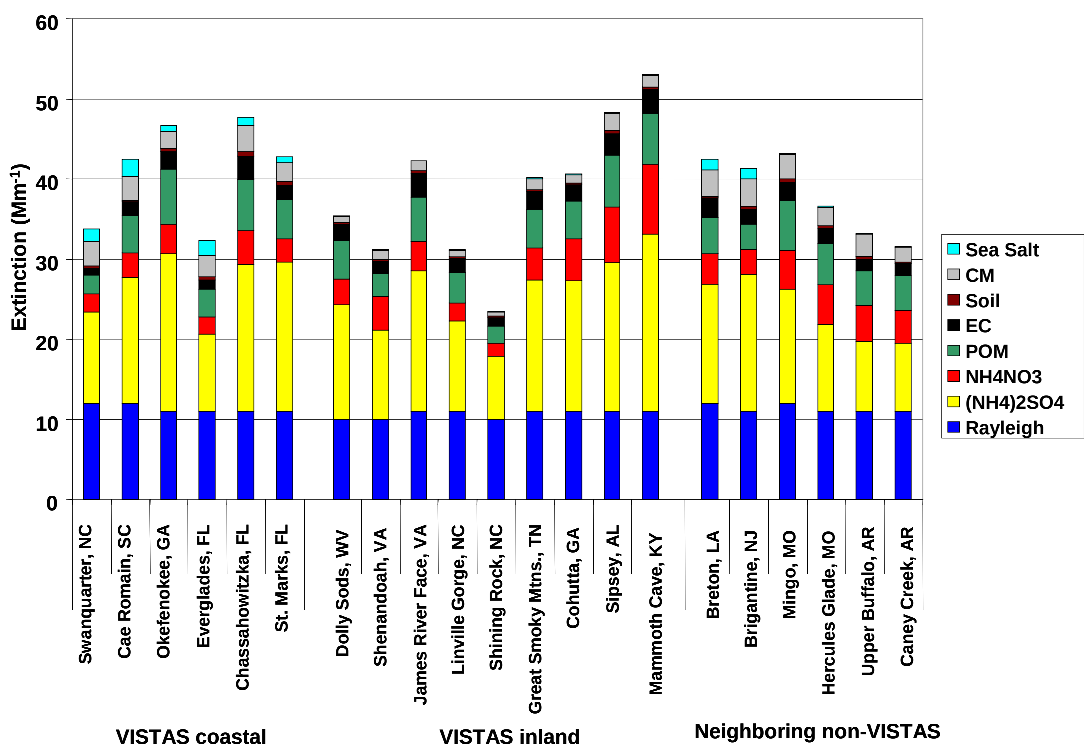


Figure 2.4-2. Average light extinction for the 20 percent Clearest Days in 2000-2004 at VISTAS and neighboring Class I areas using New IMPROVE equation

Ammonium sulfate, $(NH_4)_2SO_4$, is the most important contributor to visibility impairment and fine particle mass on the 20 percent worst (haziest) and 20 percent best (clearest) visibility days at Mammoth Cave. Sulfate levels on the 20 percent worst days account for 78 percent of the visibility impairment at Mammoth Cave. Across the VISTAS region, sulfate levels are higher at the inland sites than at the coastal sites (Figure 2.4-1). On the 20 percent clearest days, sulfate levels are more uniform across the region (Figure 2.4-2).

Sulfate particles are formed in the atmosphere from SO2 emissions. Sulfate particles occur as hydrogen sulfate, $H_2(SO_4)$, ammonium bisulfate HNH_4SO_4, and ammonium sulfate, $(NH_4)_2SO_4$, depending on the availability of ammonia, NH3, in the atmosphere.

Particulate Organic Matter (POM) is the second most important contributor to fine particle mass and light extinction on the 20 percent haziest days at the Kentucky's Class I area. Elevated levels of POM and Elemental Carbon, EC, indicate impact from wildfires or prescribed fire. Typically, in state significant fire impacts are infrequent at Kentucky's Class I area. VISTAS collected additional samples of carbon at five sites, including Mammoth Cave, KY; Great Smoky Mountains, NC; Millbrook (Raleigh, NC); Cape Romain, SC; and Shenandoah, VA, to better understand sources contributing to carbon in rural and urban areas. Samples were analyzed to define the amount of carbon-14 isotope as an indicator of the amount of carbon from modern sources (vegetative emissions, fires) and the amount of carbon from fossil sources (gasoline, diesel, oil). For most samples, the ratio of modern carbon to fossil carbon was greater than 0.60 throughout the year. In the fall, winter, and spring, more of the modern carbon is attributable to wood burning while in the summer months more of the modern carbon mass is attributable to biogenic emissions from vegetation. On some days, greater than 90% of the carbon at Great Smoky Mountains is attributable to modern sources of carbon. Biogenic carbon emissions at Cape Romain, SC, a coastal site similar to Swanquarter, were lower than emissions at the forested mountain sites. Carbon from gasoline and diesel engines is a relatively small contribution at the rural sites. At Millbrook, carbon from fossil fuel combustion is a larger percentage contribution than at the rural sites, but still less than 50 percent of total carbon measured. These results suggest that controlling anthropogenic sources of carbon will have little benefit in improving visibility in Class I areas since the majority of the POM comes from natural, i.e., biogenic, sources. Controlling anthropogenic sources of carbon will likely be more effective to reduce levels of PM2.5 in urban areas.

Ammonium nitrate, NH_4NO_3, is the second most important contributor to fine particle mass and light extinction on the 20 percent clearest days at Kentucky's Class I area. NH_4NO_3 is formed in the atmosphere by reaction of NH3 and NOx. In the VISTAS region, nitrate formation is limited by availability of NH3 and by temperature. Ammonia preferentially reacts with SO2 and sulfate before reacting with NOx. Particle nitrate is formed at lower temperatures; at elevated temperatures nitric acid remains in gaseous form. For this reason, particle nitrate levels are very low in the summer and a minor contributor to visibility impairment. Particle nitrate concentrations are higher on winter days and are more important for the coastal sites where 20 percent worst days can occur on winter days. Nitrogen oxides are emitted by fossil fuel combustion by point, area, on-road, and off-road mobile sources. Modeling data (see Section 7) indicate that in the VISTAS region ammonium nitrate formation is limited by NH3 concentrations and suggest that for winter days, controls of NH3 sources would be more effective in reducing ammonium nitrate levels than controls of NOx.

Elemental Carbon, EC, is a comparatively minor contributor to visibility impairment. Sources include agricultural and wildland (wildfire, wildland fire use and prescribed fire) burning, and incomplete combustion of fossil fuels. EC levels are higher at urban monitors than at the Class I areas and suggest controls of fossil fuel combustion sources would be more effective to reduce PM2.5 in urban areas than to improve visibility in Class I areas.

Soil fine particles are minor contributors to visibility impairment at most southeastern sites on most days. Occasional episodes of elevated fine soil can be attributed to Saharan dust episodes, particularly at Everglades, Florida, but rarely are seen at the Kentucky's Class I area. No control strategies are indicated for fine soil.

Sea salt, NaCl, is observed at the coastal sites. Sea salt contributions to visibility impairment are most important on the 20 percent clearest days when sulfate and POM levels are low. Sea salt levels do not contribute significantly to visibility on the 20 percent worst visibility days. The new IMPROVE equation uses Chloride ion, Cl^-, from routine IMPROVE measurements to calculate sea salt levels. VISTAS used Cl^- to calculate sea salt contributions to visibility following IMPROVE guidance.

Coarse particle mass (particles with diameters between 2.5 and 10 microns) has a relatively small contribution to visibility impairment because the light extinction efficiency of coarse mass is very low compared to the extinction efficiency for sulfate, nitrate, and carbon.

An *unidentified* component is reported by IMPROVE as the difference between the total PM2.5 mass measured on the filter and the sum of the measured components. This unidentified mass may be positive or negative and is attributable to water and/or the factors used to calculate molecular weights of the other components.

The New IMPROVE equation generally results in higher calculated light extinction on days with higher mass and lower light extinction on days with lower mass. This tends to increase calculated light extinction for current conditions and to decrease calculated light extinction for natural visibility conditions. Adding sea salt to the new IMPROVE equation increases light extinction for both current and natural visibility conditions. Increasing the mass multiplier for POM in the new IMPROVE equation increases light extinction for current conditions more than for natural conditions. The new algorithm does not change the conclusion that in the VISTAS region, and in Kentucky, the most effective means to improve visibility is to reduce sulfate concentrations.

PM2.5 trends in urban and Class I areas: IMPROVE data were compared to monitoring data from the Speciated Trends Network (STN) in nearby urban areas to understand the similarities and differences in composition of fine particle mass. Several PM2.5 nonattainment areas are in close proximity to the Class I areas in the southeastern United States, including Atlanta, GA; Birmingham, AL; Charleston, WV; Chattanooga, TN; Knoxville, TN; and Louisville, KY. Ammonium sulfate concentrations are comparable between urban and nearby Class I areas, while organic carbon, elemental carbon, and nitrate concentration are generally higher in urban areas than the Class I areas. These results suggest that sulfate is widely distributed regionally while urban areas see an additional incremental pollutant loading from local emissions sources.

Role of meteorology in determining visibility conditions: Classification and Regression Tree (CART) Analyses were used to characterize the relationship between meteorological conditions and visibility conditions at the Class I areas. Days were assigned to one of five visibility classes ranging from poor to good visibility. Days were then assigned to bins based on meteorological conditions. For the Kentucky's Class I area, poor visibility days were most likely to occur on days with high temperatures, high relative humidity, low wind speeds, and elevated PM2.5 mass at upwind urban areas. Precipitation was not a good predictor of visibility condition. Weights were assigned to days based on frequency of occurrence of days with similar meteorological conditions.

The above analyses are further discussed in Appendix B.

3.0 GLIDEPATHS TO NATURAL CONDITIONS IN 2064

As stated in Section 1.3, the regional haze rule directs states to graphically show what would be a "uniform rate of progress" toward natural conditions for each mandatory Class I Federal area within the State as well as for each mandatory Class I Federal area located outside the State, which may be affected by emissions from sources within the State. The uniform rate of progress is also known as the "glidepath." The glidepath is simply a straight graphical line drawn from the baseline level of visibility impairment for 2000-2004 to the level representing no manmade impairment in 2064.

Each state must set goals for each Class I area that provide for reasonable progress towards achieving natural visibility conditions by 2064. Section 51.308(d)(1) of the regional haze rule requires that reasonable progress goals must both:

(1) provide for improvement in visibility for the most impaired days over the period of the implementation plan; and
(2) ensure no degradation in visibility for the least impaired days over the same period.

Uniform rate of progress graphs (glidepaths), were developed for each Class I area in the VISTAS region. The glidepaths were developed in accordance with the USEPA's guidance for tracking progress and used data collected from the IMPROVE monitoring sites as described in Section 2 of this document. The glidepath is one of the indicators used in setting reasonable progress goals.

3.1 Glidepaths for the Class I Area in Kentucky

The following is the glidepath for the 20 percent most impaired days for Mammoth Cave National Park assuming uniform rate of progress toward regional haze goals. Natural background visibility for the most impaired days at Mammoth Cave is predicted to be 11 dv.

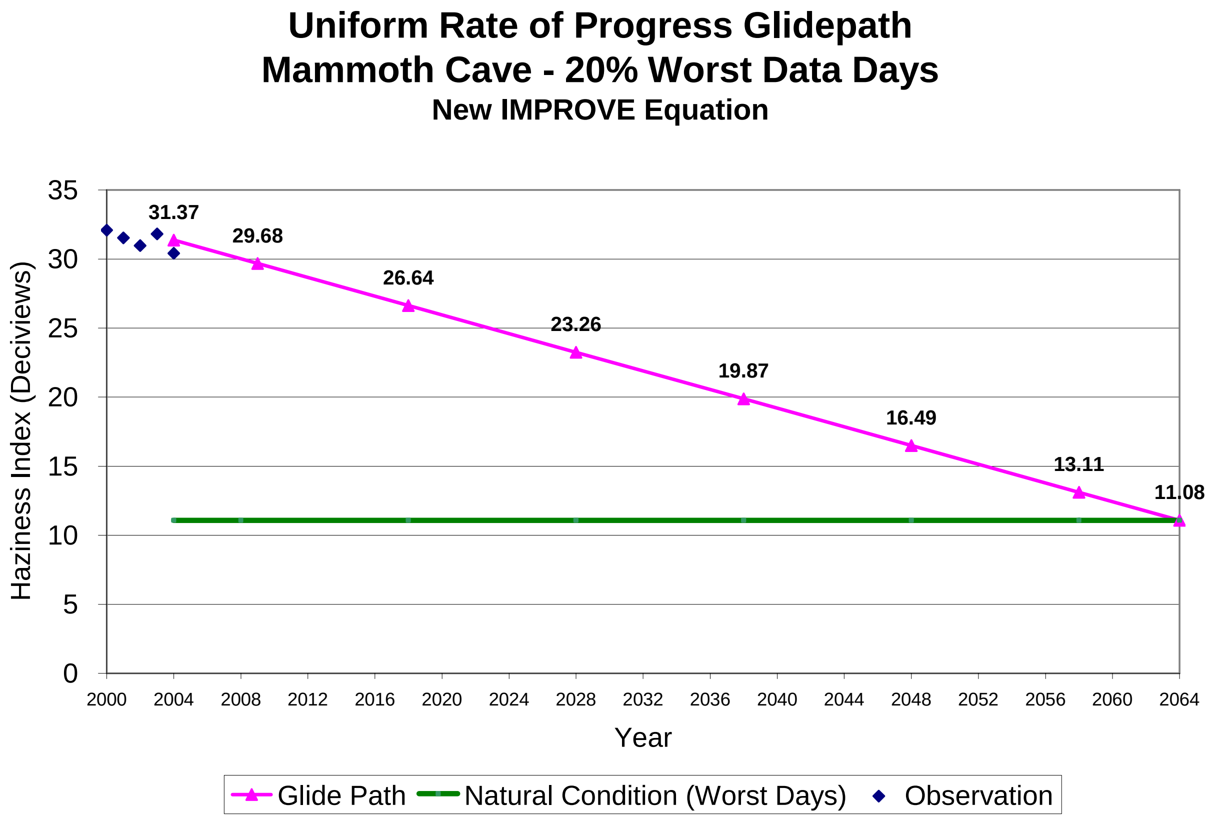


Figure 3.1-1. Uniform Rate of Progress Glidepath for 20 percent worst days at Mammoth Cave National Park.

4.0 NATURE OF THE PROBLEM: CHIEF CAUSES OF VISIBILITY IMPAIRMENT IN KENTUCKY'S CLASS I AREA

4.1 Baseline Emissions Inventory

The Regional Haze Rule at 51.308(d) (4) (v) requires a statewide emissions inventory of pollutants that are reasonably anticipated to cause or contribute to visibility impairment in any mandatory Class I area. An inventory was developed for the baseline year 2002 and projected to 2009 and 2018. The pollutants inventoried include volatile organic compounds, nitrogen oxides, fine particulate (PM2.5), coarse particulate (PM10), ammonia and sulfur dioxide. The baseline emissions inventory for 2002 was developed for Kentucky following the methods described in Appendix D.

There are five different emission inventory source classifications: stationary point and area sources, off-road and on-road mobile sources, and biogenic sources. Stationary point sources are those sources that emit greater than a specified tonnage per year, with data provided at the facility level. Electric generating utilities and industrial sources are the major categories for stationary point sources. Stationary area sources are those sources whose individual emissions are relatively small, but due to the large number of these sources, the collective emissions from the source category could be significant (i.e., dry cleaners, service stations, agricultural sources, fire emissions, etc.). These types of emissions are estimated on a countywide level. Non-road (or off-road) mobile sources are equipment that can move but do not use the roadways, i.e., lawn mowers, construction equipment, railroad locomotives, aircraft, etc. The emissions from these sources, like stationary area sources, are estimated on a countywide level. On-road mobile sources are automobiles, trucks, and motorcycles that use the roadway system. The emissions from these sources are estimated by vehicle type and road type and are summed to the countywide level. Biogenic sources are the natural sources like trees, crops, grasses and natural decay of plants. The emissions from these sources are estimated on a countywide level.

In addition to the various source classifications, there are also various types of emission inventories. The first is the actual base year inventory. This inventory is the base year emissions that correspond to the meteorological data used, which for this modeling effort is data from 2002. These emissions are used for evaluating the air quality model performance.

The second type of inventory is the typical base year inventory. This inventory is similar to the actual base year inventory, except that for sources whose emissions change significantly from year to year, a more typical emission value is used. In this modeling effort, typical emissions were developed for the electric generating units (EGUs) and the wildland fire emissions. The air quality modeling runs using the typical base year inventory provide results which are then used to calculate relative reduction factors for future years. These relative reduction factors for future years are then used to demonstrate reasonable progress toward visibility goals.

Below is an overview of the inventories used for each source classification. More detailed discussion of the emissions inventory development is contained in Appendix D.

4.1.1 Stationary Point Sources

Point source emissions are emissions from individual sources that are in a fixed location. Generally, these sources must have permits in order to construct and/or operate and their emissions are inventoried on an annual basis. All sources emitting VOC are inventoried in Kentucky's ozone nonattainment and maintenance areas on an annual basis. Large NOx sources having minimum capacity to emit 100 tons per year (tpy) of a criteria pollutant, 10 tpy of a single hazardous air pollutant (HAP), or 25 tpy total of multiple HAPs are inventoried annually. Smaller sources have been inventoried less frequently. For the purposes of this modeling point source emissions data can be grouped into EGU sources and other non-EGU sources.

<u>Electric Generating Units</u>

The actual base year inventory for the EGU sources used 2002 continuous emissions monitoring (CEM) data reported to the USEPA's Acid Rain program or 2002 hourly emissions data provided by stakeholders. These data provide hourly emissions profiles for SO2 and NOx that can be used in air quality modeling. Emissions profiles are used to estimate emissions of other pollutants (volatile organic compounds, carbon monoxide, ammonia, fine particles, soil) based on measured emissions of SO2 and NOx.

Emissions from EGUs vary daily and seasonally as a function of variability in energy demand and utilization and outage schedules. To avoid anomalies in future year emissions created by relying on 2002 operations to represent future operations, a typical base year emissions inventory was developed for EGUs. This approach is consistent with the USEPA's modeling guidance. To develop a typical year 2002 emissions inventory for EGU sources, each unit's average CEM heat input for 2000 through 2004 was divided by the 2002 actual heat input to generate a unit specific normalizing factor. This normalizing factor was then multiplied by the 2002 actual emissions. The heat inputs for the period 2000 through 2004 were used because the modeling of current conditions use monitored data from this same 5-year period. If a unit was shut down for an entire year during the 2000 through 2004 period, the average of the years the unit was operational was used. If a unit was shut down in 2002, but not permanently shutdown, the emissions and heat inputs from 2001 (or 2000) were used in the normalizing calculations.

As part of the VISTAS air quality modeling, VISTAS, in cooperation with the other eastern RPOs, contracted with ICF Resources, L.L.C., to generate future year emission inventories for the electric generating sector of the contiguous United States using the Integrated Planning Model (IPM) version 2.1.9 updated with state-specific information. IPM is a dynamic linear optimization model that can be used to examine air pollution control policies for various pollutants throughout the contiguous United States for the entire electric power system. The dynamic nature of IPM enables projection of the behavior of the power system over a specified future period. Optimization logic in IPM determines the least-cost means of meeting electric generation and capacity requirements while complying with specified constraints including air pollution regulations, transmission bottlenecks, and plant-specific operational constraints. The versatility of IPM allows users to specify which constraints to exercise, and to populate IPM with their own datasets.

The IPM modeling runs took into consideration the USEPA's Clean Air Interstate Rule (CAIR) implementation and North Carolina's CSA requirements.

Other Industrial Point Sources

For the non-EGU sources, the same inventory is used for both the actual and typical base year emissions inventories. The non-EGU category uses annual emissions as reported under the Consolidated Emissions Reporting Rule (CERR) for the year 2002. These emissions are temporally allocated to month, day, and hour using source category code (SCC)-based allocation factors.

The general approach for assembling future year data was to use recently updated growth and control data consistent with USEPA's CAIR analyses. This data was supplemented with state-specific growth factors and stakeholder input on growth assumptions.

4.1.2 Stationary Area Sources

Stationary area sources are sources whose individual emissions are relatively small, but due to the large number of these sources, the collective emissions could be significant (i.e., combustion of fuels for heating, structure fires, service stations, etc.). Emissions are estimated by multiplying an emission factor by some known indicator of collective activity, such as fuel usage, number of households, or population. Stationary area source emissions are estimated at the countywide level.

A small portion of the 2002 area source base year inventory for ozone precursors in eleven Kentucky ozone areas was developed by the KYDAQ and provided to the VISTAS contractor. The VISTAS contractor calculated the remaining portion of the area source inventory. The sources estimated by the contractor include emissions from animal husbandry, wildland fires, and particulate matter from paved and unpaved roads. For the other states within the modeling domain, either state-supplied data or data reported under CERR for 2002 was used.

The actual base year inventory will serve as the typical base year inventory for all area source categories except for wildland fires. For wildland fires, a typical year inventory was used to avoid anomalies in wildfire activity in 2002 compared to longer term averages. Development of a typical year fire inventory provided the capability of using a comparable data set for both the base year and future years. The VISTAS Fire Special Interest Work Group used State records to ratio the number of acres burned over a longer term period (three or more years, as available from state records) to 2002. Based on these ratios, the 2002 acreage was then scaled up or down to develop a typical year inventory.

The VISTAS contractor generated future year emissions inventories for 2009 and 2018 for the regional haze modeling. Growth factors, supplied either by states or taken from the CAIR emission projections, were applied to project the controlled emissions to 2018. If no growth factor was available from either a state or the CAIR growth factor files, then the USEPA's Economic Growth and Analysis System Version 5 growth factors were used.

4.1.3 Off-Road Mobile Sources

Off-road (or non-road) mobile sources are equipment that can move but do not use the roadways, such as construction equipment, aircraft, railroad locomotives, lawn and garden equipment, etc. For the majority of the non-road mobile sources, the emissions for 2002 were estimated using the USEPA's NONROAD2005c model. For the three source categories not included in the NONROAD model, i.e., aircraft engines, railroad locomotives and commercial marine, more traditional methods of estimating the emissions were used. The same inventory is used for both the actual and typical base year emissions inventories.

For the source categories estimated using the USEPA's NONROAD model, the model growth assumptions were used to create the 2009 and 2018 future year inventories. The NONROAD model takes into consideration regulations affecting emissions from these source categories**.** For the Northern Kentucky Greater Cincinnati International Airport, KYDAQ confirmed to the VISTAS contractor the number of landings and takeoffs for 2002. For the commercial marine, railroad locomotives and the remaining airport emissions, the VISTAS contractor calculated the future growth in emissions using detailed inventory data (both before and after controls) for 1996 and 2010, obtained from the CAIR Technical Support Document. When available, state-specific growth factors were used.

4.1.4 Highway Mobile Sources

For onroad vehicles, the newest version of the MOBILE model, MOBILE6.2, was used. Key inputs for MOBILE include information on the age of vehicles on the roads, the average speeds on the roads, the mix of vehicles on the roads, any programs in place in an area to reduce emissions for motor vehicles (e.g., emissions inspection programs), and temperature.

The MOBILE model takes into consideration regulations that affect emissions from this source sector. The same MOBILE run is used to represent the actual and typical year emissions for onroad vehicles using input data reflective of 2002. The MOBILE model then is run for 2018 inventory using input data reflective of that year. KYDAQ provided 2002 and 2018 VMT and speed information to the VISTAS contractor for a small number of Kentucky counties. For several urban areas in Kentucky that run travel demand models (TDMs), VMT and speed data from TDMs was obtained by KYDAQ and provided to the VISTAS contractor.

4.1.5 Biogenic Emission Sources

Biogenic emissions were prepared with the SMOKE-BEIS3 (Biogenic Emission Inventory System 3 version 0.9) preprocessor. SMOKE-BEIS3 is a modified version of the Urban Airshed Model (UAM)-BEIS3 model. Modifications include use of MM5 data, gridded land use data, and improved emissions characterization. The emission factors that are used in SMOKE-BEIS3 are the same as the emission factors as in UAM-BEIS3. The basis for the gridded land use data used by BEIS3 is the county land use data in the Biogenic Emissions Landcover Database version 3 (BELD3) provided by the USEPA. A separate land classification scheme, based upon satellite (AVHRR, 1 km spatial resolution) and census information, aided in defining the forest, agriculture and urban portions of each county.

4.1.6 Summary 2002 Baseline Emissions Inventory for Kentucky

Table 4.1.6-1 is a summary of the 2002 baseline emission inventory for Kentucky. The complete inventory and discussion of the methodology is contained in Appendix D. The emissions summaries for other VISTAS states can also be found in Appendix D.

Table 4.1.6-1 2002 Emissions Inventory Summary for Kentucky (tons per year).

	VOC	NOx	PM2.5	PM10	NH3	SO2
Point	46,315	240,362	14,219	21,421	995	529,182
Area	98,713	40,966	51,763	240,226	51,246	41,941
On-Road Mobile	103,503	156,417	2,697	3,723	5,055	6,308
Non-Road Mobile	44,805	104,571	6,046	6,425	31	14,043
Biogenics	630,506	21,090	0	0	0	0
TOTAL	923,842	563,406	74,725	271,795	57,327	591,474

4.1.7 Model Performance Improvements through Emissions Inventory Improvements

Since the initial model performance evaluation, VISTAS has made several improvements to the emissions inventory, which in turn improved model performance. These inventory improvements are detailed in the VISTAS emissions inventory report and Appendix D, and are summarized here:

- For electric generating utilities, the Integrated Planning Model (IPM) was used to provide estimates of future year utility production and emissions. Continuous Emissions Monitoring data was used to define seasonal variability in production and emissions. The states updated IPM model projections with control data provided by utility companies in late 2006 through early 2007.
- For on-road vehicle emissions, states and local agencies provided updated MOBILE model input and vehicle-miles-traveled data.
- For ammonia emissions from agricultural sources, the Carnegie Mellon University ammonia model was used to improve annual and monthly estimates.
- For fires, the VISTAS states provided fire activity data for 2002 for wildfires, prescribed fire, land clearing and agricultural burning to develop a 2002 fire inventory. Where data allowed, large fire events were modeled as point sources. In 2006, the United States Forest Service and Fish and Wildlife Service provided projections of increased prescribed burning in 2009 and 2018; these data were incorporated in the inventory for all states except Florida. Because current prescribed fire activity already reflects the use of fire as a forest management technique, Florida believed that there is too much uncertainty to project how future total fire activity (prescribed plus wildfire) will change. In Florida, prescribed fire in the future years is the same as 2002 typical for prescribed fire.
- For non-road engines, the updated USEPA NONROAD2005 emissions model was used.
- For commercial marine emissions in shipping lanes in the Gulf of Mexico and Atlantic Oceans, gridded emissions for the VISTAS modeling domain was created using inventory data newly developed for the USEPA by Corbett at University of Delaware. These emissions were incorporated in the modeling.
- Updated inventories from the neighboring RPOs, Mexico, and Canada were incorporated as available.

4.2 Assessment of Relative Contributions from Specific Pollutants and Sources Categories

Ammonium sulfate is the largest contributor to visibility impairment at Kentucky's Class I area and reduction of SO2 emissions would be the most effective means of reducing ammonium sulfate. As illustrated in Figure 4.2-1, 96 percent of SO2 emissions in the VISTAS states are attributable to electric generating facilities and industrial point sources. Similarly, in Kentucky the stationary point sources, consisting of electric generating facilities and industrial point sources, contribute 90 percent of the SO2 emissions as illustrated in Figure 4.2-2.

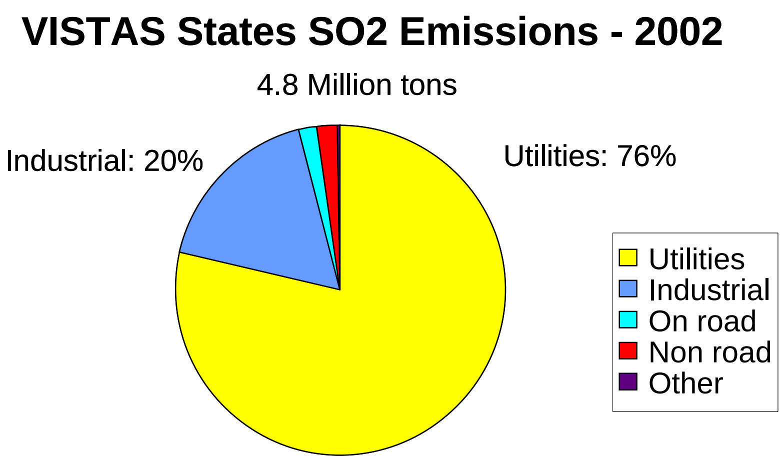


Figure 4.2-1. SO2 emissions in 2002 in the VISTAS States.

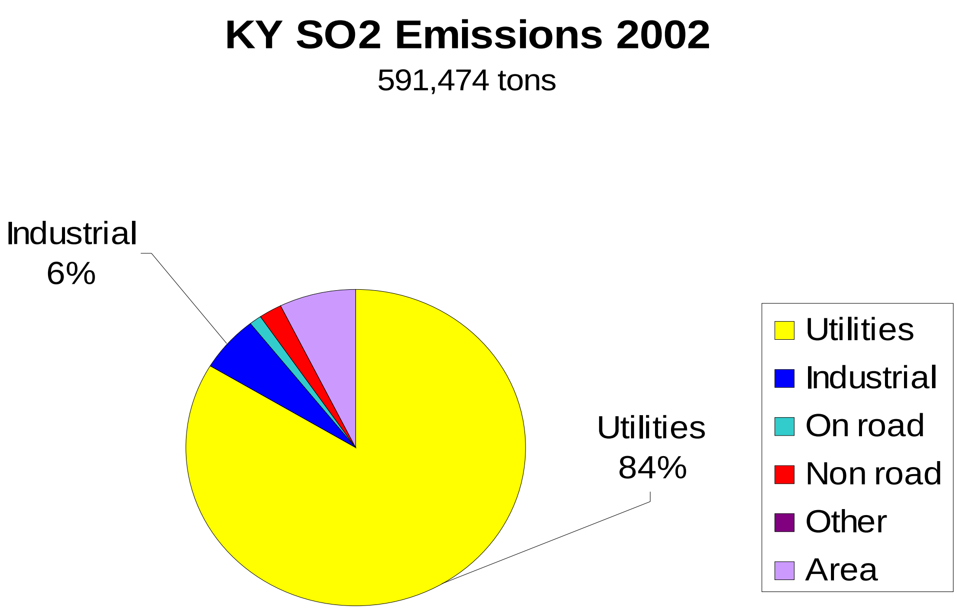


Figure 4.2-1. SO2 emissions in 2002 in Kentucky.

Since the largest source of SO_2 emissions comes from the stationary point sources, the focus of potential controls and the impacts for those controls was on this source sector. In Kentucky, the types of sources emitting SO_2, and thus contributing to the visibility impairment of its Class I area, were predominately coal fired utility and industrial boilers.

5.0 REGIONAL HAZE MODELING METHODS AND INPUTS

Modeling for regional haze was performed by VISTAS for the ten southeastern states, including Kentucky. The sections below outline the methods and inputs used by VISTAS for the regional modeling. Additional details are provided in Appendices C, D and M.

5.1 Analysis Method

The modeling analysis is a complex technical evaluation that begins by selection of the modeling system. VISTAS decided to use the following modeling system:

- Meteorological Model: The Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) Mesoscale Meteorological Model (MM5) is a nonhydrostatic, prognostic meteorological model routinely used for urban- and regional-scale photochemical, fine particulate matter, and regional haze regulatory modeling studies.
- Emissions Model: The Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system is an emissions modeling system that generates hourly gridded speciated emission inputs of mobile, nonroad mobile, area, point, fire and biogenic emission sources for photochemical grid models.
- Air Quality Model: The USEPA's Models-3/ Community Multiscale Air Quality (CMAQ) modeling system is an 'One-Atmosphere' photochemical grid model capable of addressing ozone, particulate matter (PM), visibility and acid deposition at regional scale.

The USEPA's 2007 modeling guidance recommends modeling an entire year or at a minimum several days in each quarter of a year to adequately represent the range of meteorological conditions that contribute to elevated levels of fine particulate matter. The year 2002 was selected by VISTAS as the modeling year for this demonstration. Meteorological inputs were developed for 2002 using the meteorological model. Emission inventories were also developed for 2002 and processed through the emissions model. These inputs were used in the air quality model to predict fine particle mass and visibility. The model results for 2002 were compared with observed meteorological and air quality data to evaluate model performance. Several configurations of the meteorological and air quality model were evaluated to select a configuration that gave the best overall performance for the VISTAS region.

Once model performance was deemed adequate, the current and future year emissions were processed through the emissions model. The air quality modeling results are used to determine a relative reduction in future visibility impairment, which is used to determine reasonable progress.

The complete modeling protocol used for this analysis can be found in Appendix C.

5.2 Model Selection

To ensure that a modeling study is defensible, care must be taken in the selection of the models to be used. The models selected must be scientifically appropriate for the intended application and be freely accessible to all stakeholders. “Scientifically appropriate” means that the models address important physical and chemical phenomena in sufficient detail, using peer-reviewed methods. “Freely accessible” means that model formulations and coding are freely available for review and that the models are available to stakeholders, and their consultants, for execution and verification at no or low cost.

The following sections outline the criteria for selecting a modeling system that is both defensible and capable of meeting the study's goals. These criteria were used in selecting the modeling system used for this modeling demonstration.

5.2.1 Selection of Photochemical Grid Model

Criteria

For a photochemical grid model to qualify as a candidate for use in a regional haze SIP, a State needs to show that it meets the same several general criteria as a model for an attainment demonstration for a NAAQS:

- The model has received a scientific peer review
- The model can be demonstrated applicable to the problem on a theoretical basis
- Data bases needed to perform the analysis are available and adequate
- Available past appropriate performance evaluations have shown the model is not biased toward underestimates or overestimates
- A protocol on methods and procedures to be followed has been established
- The developer of the model must be willing to make the source code available to users for free or for a reasonable cost, and the model cannot otherwise be proprietary.

Overview of CMAQ

The photochemical model selected for this study was CMAQ version 4.5, with (SOAmods), secondary organic aerosol (SOA) modifications that were developed by the VISTAS contractor in order to improve organic carbon under prediction performance in the VISTAS modeling (See Appendix C for published article regarding the SOA modifications). For more than a decade, the USEPA has been developing the Models-3 CMAQ modeling system with the overarching aim of producing a ‘One-Atmosphere’ air quality modeling system capable of addressing ozone, fine particulate matter, visibility and acid deposition within a common platform. The original justification for the Models-3 development emerged from the challenges posed by the 1990

CAAA and the USEPA's desire to develop an advanced modeling framework for 'holistic' environmental modeling utilizing state-of-science representations of atmospheric processes in a high performance computing environment. The USEPA completed the initial stage of development with Models-3 and released the CMAQ model in mid-1999 as the initial operating science model under the Models-3 framework. The most recent rendition is CMAQ version 4.5, which was released in September 2005. Please note that VISTAS used a previous version of the CMAQ model (CMAQv4.4_SOAmods) in earlier VISTAS sensitivity work.

An advantage of choosing CMAQ as the atmospheric model is the ability to do one-atmospheric modeling. The same model configuration is being applied for the ozone and PM2.5 attainment demonstrations SIPs, as well as the regional haze SIP. A number of features in CMAQ's theoretical formulation and technical implementation make the model well suited for annual PM modeling.

The configuration used for this modeling demonstration, as well as a more detailed description of the CMAQ model, can be found in the Modeling Protocol (Appendix C).

5.2.2 Selection of Meteorological Model

Criteria

Meteorological models, either through objective, diagnostic, or prognostic analysis, extend available information about the state of the atmosphere to the grid upon which photochemical grid modeling is to be carried out. The criteria for selecting a meteorological model are based on both the models ability to accurately replicate important meteorological phenomena in the region of study, and the model's ability to interface with the rest of the modeling systems -- particularly the photochemical grid model. With these issues in mind, the following criteria were established for the meteorological model to be used in this study:

- Non-Hydrostatic Formulation
- Reasonably current, peer reviewed formulation
- Simulates Cloud Physics
- Publicly available at no or low cost
- Output available in I/O API format
- Supports Four Dimensional Data Assimilation (FDDA)
- Enhanced treatment of Planetary Boundary Layer heights for AQ modeling

Overview of MM5

The non-hydrostatic MM5 model is a three-dimensional, limited-area, primitive equation, prognostic model that has been used widely in regional air quality model applications. The basic model has been under continuous development, improvement, testing and open peer-review for more than 20 years and has been used worldwide by hundreds of scientists for a variety of mesoscale studies.

MM5 uses a terrain-following non-dimensionalized pressure, or "sigma", vertical coordinate similar to that used in many operational and research models. In the non-hydrostatic MM5, the sigma levels are defined according to the initial hydrostatically-balanced reference state so that the sigma levels are also time-invariant. The gridded meteorological fields produced by MM5 are directly compatible with the input requirements of ‘one atmosphere’ air-quality models using this coordinate. MM5 fields can be easily used in other regional air quality models with different coordinate systems by performing a vertical interpolation, followed by a mass-conservation re-adjustment.

Distinct planetary boundary layer parameterizations are available for air-quality applications, both of which represent sub-grid-scale turbulent fluxes of heat, moisture and momentum. One scheme uses a first-order eddy diffusivity formulation for stable and neutral environments and a modified first-order scheme for unstable regimes. The other scheme uses a prognostic equation for the second-order turbulent kinetic energy, while diagnosing the other key boundary layer terms.

Initial and lateral boundary conditions are specified for real-data cases from mesoscale three-dimensional analyses performed at 12-hour intervals on the outermost grid mesh selected by the user. Surface fields are analyzed at three-hour intervals. A Cressman-based technique is used to analyze standard surface and radiosonde observations, using the National Meteorological Center's spectral analysis, as a first guess. The lateral boundary data are introduced using a relaxation technique applied in the outermost five rows and columns of the coarsest grid domain.

The MM5 modeling system in regulatory air quality application studies has been widely reported in the literature (e.g., Emery et al., 1999; Tesche et al., 2000, 2003) and many have involved comparisons with other prognostic models such as the Regional Atmospheric Modeling System (RAMS) and the Systems Application International Mesoscale Model. The MM5 enjoys a far richer application history in regulatory modeling studies compared with RAMS or other models. Furthermore, in evaluations of these models in over 60 recent regional scale air quality application studies since 1995, it has generally been found that the MM5 model tends to produce somewhat better photochemical model inputs than alternative models.

The configuration used for this modeling demonstration, as well as a more detailed description of the MM5 model, can be found in the meteorological modeling protocol (Appendix E).

5.2.3 Selection of Emissions Processing System

Criteria

The principal criterion for an emissions processing system is that it accurately prepares emissions files in a format suitable for the photochemical grid model being used. The following list includes clarification of this criterion and additional desirable criteria for effective use of the system.

- File System Compatibility with the I/O API
- File Portability
- Ability to grid emissions on a Lambert Conformal projection
- Report Capability
- Graphical Analysis Capability
- MOBILE6 Mobile Source Emissions
- Biogenic Emissions Inventory System version 3 (BEIS-3)
- Ability to process emissions for the proposed domain in a reasonable amount of time.
- Ability to process control strategies
- No or low cost for acquisition and maintenance
- Expandable to support other species and mechanisms

Overview of SMOKE

The SMOKE Emissions Processing System Prototype was originally developed at the Micro-computing Center of North Carolina. As with most 'emissions models', SMOKE is principally an *emission processing system* and not a true *emissions modeling system* in which emissions estimates are simulated from 'first principles'. This means that, with the exception of mobile and biogenic sources, its purpose is to provide an efficient, modern tool for converting emissions inventory data into the formatted emission files required by an air quality simulation model. For mobile sources, SMOKE actually estimates emissions based on input mobile-source activity data, emission factors and outputs from transportation travel-demand models.

SMOKE was originally designed to allow emissions data processing methods to utilize emergent high-performance-computing as applied to sparse-matrix algorithms. Indeed, SMOKE is the fastest emissions processing tool currently available to the air quality modeling community. The sparse matrix approach utilized throughout SMOKE permits both rapid and flexible processing of emissions data. The processing is rapid because SMOKE utilizes a series of matrix calculations instead of less efficient algorithms used in previous systems. The processing is flexible because the processing steps of temporal projection, controls, chemical speciation, temporal allocation, and spatial allocation have been separated into independent operations wherever possible. The results from these steps are merged together at a final stage of processing.

SMOKE contains a number of major features that make it an attractive component of the modeling system. The model supports a variety of input formats from other emissions processing systems and models. It supports both gridded and county total land use scheme for biogenic emissions modeling. SMOKE can accommodate emissions files from up to 10 countries and any pollutant can be processed by the system. For additional information about the SMOKE model please refer to Modeling Protocol (Appendix C).

5.3 Selection of the Modeling Year

A crucial step to SIP modeling is the selection of the period of time to model to represent current air quality conditions and to project changes in air quality in response to changes in emissions. The year 2002 was selected as the base year for several reasons.

The USEPA's April 2007 *Guidance on the use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze* identifies specific goals to consider when selecting one or more episodes for use in demonstrating reasonable progress in attaining the regional haze air quality goals. The USEPA recommends that episode selection derive from three principal criteria:

- Simulate a variety of meteorological conditions;
- Model time periods in which observed concentrations are close to the appropriate baseline design value or visibility impairment;
- Model periods for which extensive air quality/meteorological data bases exist; and
- Model a sufficient number of days so that the modeled attainment test applied at each monitor violating the NAAQS is based on multiple days.

For regional haze modeling, the guidance goes further by suggesting that the preferred approach is to model a full, *representative* year. Moreover, the required relative reduction factor values should be based on model results averaged over the 20% worst and 20% best visibility days determined for each Class I area based on monitoring data from the 2000 – 2004 baseline period.

The USEPA also lists several other considerations to bear in mind when choosing potential regional haze episodes including: (a) choose periods which have already been modeled, (b) choose periods which are drawn from the years upon which the current design values are based, (c) include weekend days among those chosen, and (d) choose modeling periods that meet as many episode selection criteria as possible in the maximum number of nonattainment or Class I areas as possible. Finally, the USEPA explicitly recommended in its 2007 modeling guidance to use 2002 as the baseline inventory year.

VISTAS adopted a logical, stepwise approach in implementing the USEPA's 2007 modeling guidance in order to identify the most preferable, representative year for regional haze modeling. These steps include the following:

> <u>Representativeness of Meteorological Conditions:</u> The VISTAS meteorological contractor (BAMS) identified important meteorological characteristics and data sets in the VISTAS region directly relevant to the evaluation of candidate annual modeling episodes.
>
> <u>Initial Episode Typing:</u> At the time of selection in 2003, meteorological and air quality data were available for 2002 for model inputs and model performance evaluation. VISTAS used CART analyses to evaluate visibility conditions for 2000, 2001, and 2002,

the candidate modeling years. The year 2002 was found to be representative of conditions in the other two years. Subsequently, these analyses were repeated with the meteorological and air quality monitoring data for 2000 to 2004 to evaluate how well the 2002 modeling year represented the full 2000-2004 baseline period. This analysis confirmed that visibility and PM2.5 mass in 2002 were representative of the five-year baseline period for the VISTAS Class I areas. This analysis is discussed in more detail in the project report in Appendix B.

Data Availability: In parallel with the CART analyses, episode characterization analyses, collaborative investigations by VISTAS states (e.g., NCDAQ, Georgia Department of Natural Resources, Florida Department of Environmental Protection) intensively studied the availability of PM2.5, meteorological, and emissions data and representativeness of alternative baseline modeling periods from a regulatory standpoint. Additionally, 2002 was the year that the USEPA was requiring states to provide emissions inventory data for the Comprehensive Emissions Reporting Rule, it made sense to use 2002 as the modeling year to take advantage of the 2002 inventory.

Years to be used by other RPOs: VISTAS also considered what years other RPO would be modeling, and several had already chosen calendar year 2002 as the modeling year.

After a lengthy process of integrated studies, the episode selection process culminated in the selection of calendar year 2002 (1 January through 31 December) as the most current, representative, and pragmatic choice for VISTAS regional haze modeling. All of the USEPA criteria for regional haze episode selection were directly considered in this process together with many other considerations (e.g., timing of new emissions or aerometric data deliveries by the USEPA or the states to the modeling teams).

5.4 Modeling Domains

5.4.1 Horizontal Modeling Domain

The USEPA’s 2007 modeling guidance recommends a 12-km modeling grid resolution for PM2.5 modeling while a 36-km grid is considered acceptable for regional haze. For the VISTAS modeling, a coarse 36-km grid resolution was used for modeling the entire United States and a finer 12-km grid was used to model the eastern United States.

The CMAQ model was run in one-way nested grid mode. This allowed the larger outer domains to feed concentration data to the inner nested domain. Two-way nesting was not considered due to numerical and computational uncertainty associated with the technique.

The horizontal coarse grid modeling domain boundaries were determined through a national effort to develop a common grid projection and boundary. A smaller 12-km grid, modeling domain was selected in an attempt to balance location of areas of interest, such as ozone and fine particulate matter nonattainment areas, as well as Class 1 areas for regional haze. Processing time was also a factor in choosing a smaller 12-km grid, modeling domain.

The coarse 36-km horizontal grid domain covers the continental United States. This domain was used as the outer grid domain for MM5 modeling with the CMAQ domain nested within the MM5 domain. Figure 5.4.1-1 shows the MM5 horizontal domain as the outer most, blue grid with the CMAQ 36-km domain nested in the MM5 domain.

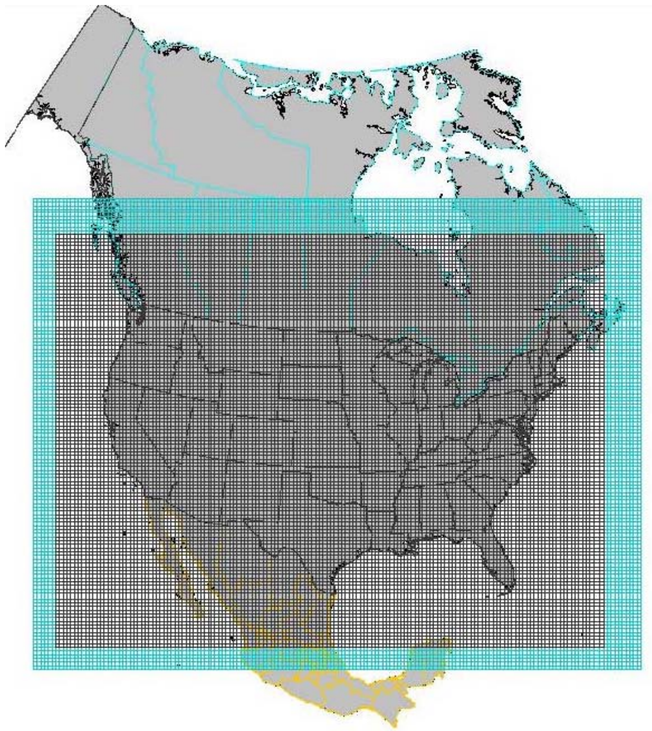


Figure 5.4.1-1. The MM5 horizontal domain is the outer most, blue grid, with the CMAQ 36-km domain nested in the MM5 domain.

To achieve finer spatial resolution in the VISTAS states, a one-way nested high resolution (12-km grid resolution) was used. Figure 5.4.1-2 shows the 12-km grid, modeling domain for the VISTAS region. The modeling results from this modeling domain are the results on which the reasonable progress goals will be assessed.

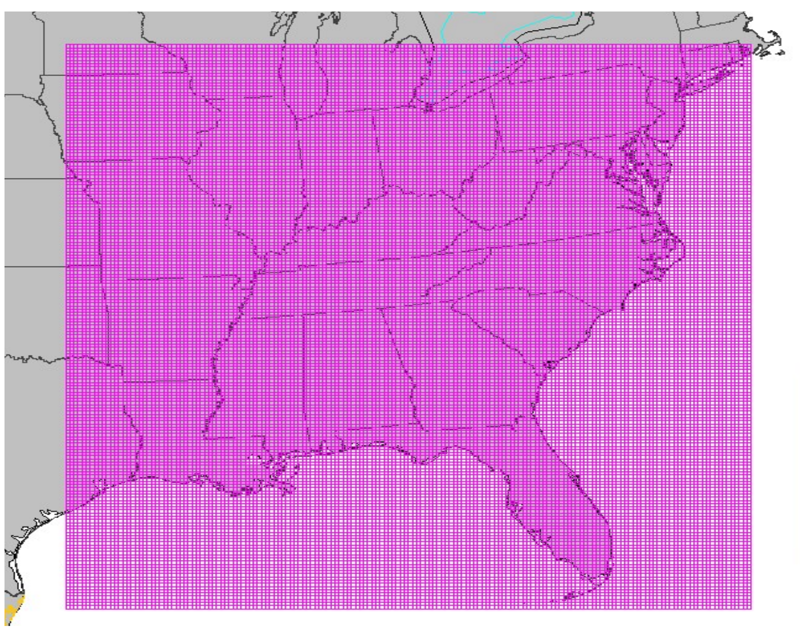


Figure 5.4.1-2. A more detailed view of the 12-km grid over the VISTAS region.

5.4.2 Vertical Modeling Domain

The CMAQ vertical structure is primarily defined by the vertical grid used in the MM5 modeling. The MM5 model employed a terrain following coordinate system defined by pressure, using 34 layers that extend from the surface to the 100 mb. A layer-averaging scheme was used to generate 19 vertical layers for CMAQ to reduce the computational cost of the CMAQ simulations. The effects of layer averaging were evaluated in conjunction with the VISTAS modeling effort and was found to have a relatively minor effect on the model performance metrics when both the 34 layer and a 19 layer CMAQ models were compared to ambient monitoring data.

6.0 MODEL PERFORMANCE EVALUATION

The initial modeling effort focused on evaluating previous regional air quality modeling applications and testing candidate model configurations for the SMOKE emissions and CMAQ model for the VISTAS 36-km and 12-km modeling domains. This effort resulted in a report recommending the model configuration for the annual emissions and air quality modeling, which is included as part of the VISTAS Emissions and Air Quality Modeling Protocol. The evaluation of the meteorological modeling configuration can be found in Appendix F.1, with a summary of the final meteorological and air quality modeling configuration in the modeling protocol contained in Appendix E and Appendix C, respectively.

Air quality model performance for the 2002 modeling year was initially tested in 2004 using an early version of the VISTAS emissions inventory. In keeping with the one-atmosphere objective of the CMAQ modeling platform, model performance was evaluated based on measured ozone, fine particles, and acid deposition in the Air Quality System (AQS), IMPROVE, Speciated Trends Network (STN), Southeastern Aerosol Research and Characterization (SEARCH), National Acid Deposition Program (NADP) and Clean Air Status and Trends Network (CASTNet) monitoring networks (Figure 6.0-1). A detailed examination of the results was published in 2005 in the Journal of Air and Waste Management (see Appendix B.3) as well as being summarized in Appendix B.1.

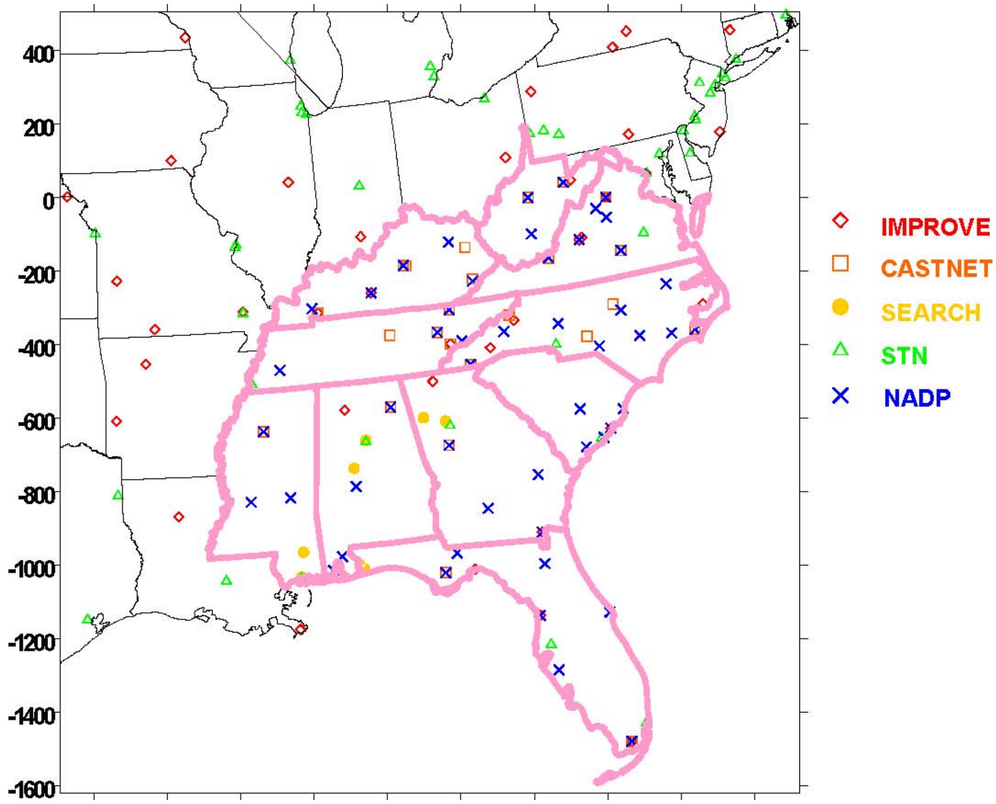


Figure 6.0-1: Monitoring Networks used for VISTAS 2002 model performance evaluation, and their location within the VISTAS 12km domain.

6.1 Modeling Performance Goals, and Criteria

In 2004, VISTAS established model performance goals and criteria for components of fine particle mass (Table 6.1-1) based on previous model performance for ozone and fine particles. The USEPA's 2007 modeling guidance for fine particulate matter at the time noted that PM models might not be able to achieve the same level of performance as ozone models. VISTAS's evaluation considered several statistical performance measures and displays. Fractional bias and mean fractional error were selected as the most appropriate metrics to summarize model performance; other metrics were also calculated and are included for IMPROVE monitors in the full model performance evaluation (Appendix F.2).

Table 6.1-1: Established model performance goals and criteria for the component species of fine particle mass.

Fractional Bias	Mean Fractional Error	Comment
≤15 percent	≤35 percent	Goal for PM model performance based on ozone model performance, considered excellent performance
≤30 percent	≤50 percent	Goal for PM model performance, considered good performance
≤60 percent	≤75 percent	Criteria for PM model performance, considered average performance. Exceeding this level of performance indicates fundamental concerns with the modeling system and triggers diagnostic evaluation.

Several graphic displays of model performance were prepared including:

1. Scatter plots of predicted and observed concentrations and deposition by species, monitoring network, and month
2. Time series plots of predicted and observed concentrations and deposition by species, monitoring site, and month
3. Spatially average time series plots
4. Time series plots of monthly fractional bias and error for a species, region, and network
5. Performance goal plots ("soccer plots") that summarize model performance by species, region, season
6. Concentration performance plots ("bugle plots") that display fractional bias or error as a function of concentration by species, region, monitoring network, and month

The "soccer plots" and "bugle plots" are relatively new tools in model performance evaluations, and have recently been included as model performance evaluation displays in the USEPA's 2007 modeling guidance for ozone, PM2.5, and regional haze. Both "soccer plots" and "bugle plots" allow for convenient way to examine model performance with respect to set goals and criteria. The bugle plots have the added benefit of adjusting the goals and criteria to consider the concentration of the species. Analysis of "bugle plots" generally suggests that greater emphasis should be placed on performance of those components with the greatest contribution to PM mass and visibility impairment (e.g. sulfate and organic carbon) and that greater bias and error could be accepted for components with smaller contributions to total PM mass (e.g. elemental carbon, nitrate, and soil).

6.2 VISTAS Domain-Wide Performance

Further discussion of model performance in this document will focus on the comparison of observational data from the IMPROVE monitors and model output data from the VISTAS 2002 actual annual air quality modeling. Focus is limited to the IMPROVE monitoring network as these sites are the locations used in projecting visibility improvement goals in the Class I areas.

The evaluation will primarily focus on the air quality model's performance with respect to individual components of PM2.5, as good model performance of the component species will dictate good model performance of total or reconstituted PM2.5. Model performance of the total PM2.5 and the resulting total light extinction will also be provided as a means to discuss the overall model performance for this SIP.

In the analyses, mean fractional bias (error) is used in lieu of mean bias (error), to prevent low observations and model predictions from skewing the metrics. A full list of model performance statistics is found in Appendix F.2. The soccer and bugle plots for the all of the VISTAS IMPROVE monitors are included here for summary purposes. The goal and criteria levels used for regional haze model performance were 30% and 60%, respectively, for mean fractional bias and 50% and 75%, respectively, for mean fractional error. Plots have been developed for the average monthly concentrations and the performance statistics for all of the most significant light scattering component species (Sulfate, Nitrate, and Organic Carbon) for the 20% best days and 20% worst days. Plots for individual IMPROVE monitors associated with Kentucky's Class I area are included in Appendix F.2.

The soccer plots of monthly concentrations (Figures. 6.2-1 and 6.2-2) show that values for nitrate generally fall outside of criteria performance thresholds (red box). Sulfates and organic carbon generally fall within goal thresholds (green box), with a couple of months falling just outside the goal thresholds but well within the criteria thresholds. In these figures, each point represents a month. Figure 6.2-3 contains separate soccer plots for each season. The seasonal plots emphasize poorer nitrate performance in the summer, when observed nitrate is quite low and predicted nitrate is even lower. When concentration is factored into performance criteria, nitrate performance improves with respect to mean fractional bias and mean fractional error (Figures 6.2-4 and 6.2-5).

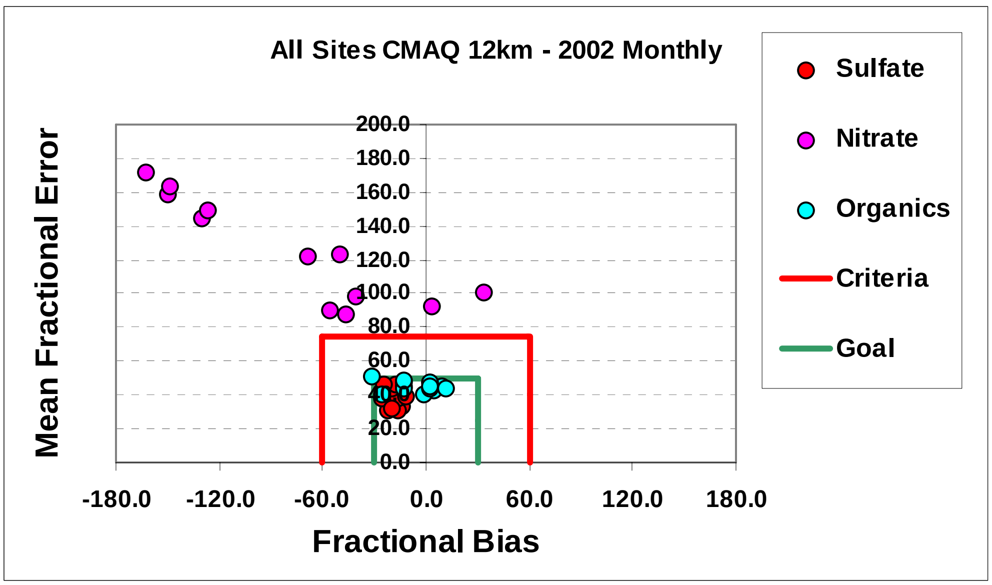


Figure 6.2-1: Soccer plot depicting both the mean fractional error and fractional bias for component concentration for all VISTAS sites.

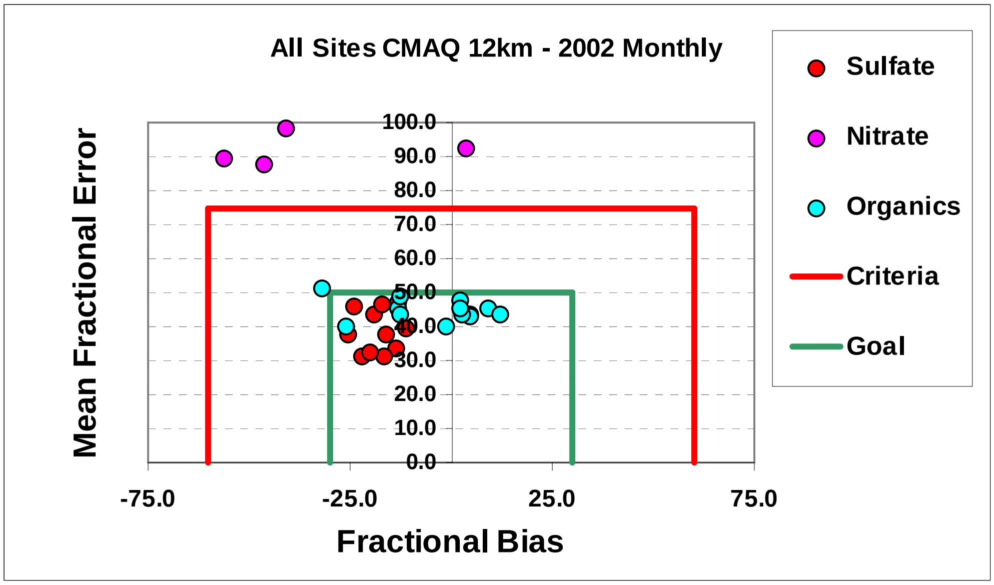


Figure 6.2-2: A zoomed view of the soccer plot depicting both the mean fractional error and fractional bias for component concentration for all VISTAS sites.

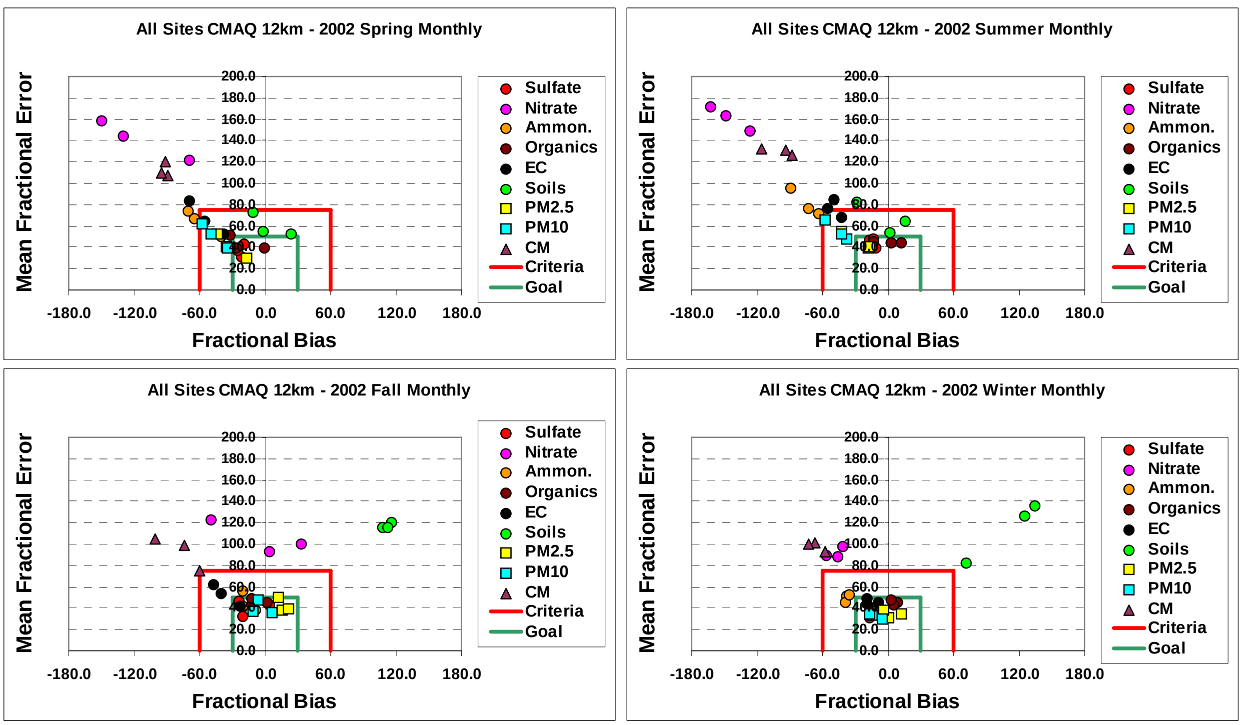


Figure 6.2-3: Seasonal soccer plots for all VISTAS IMPROVE monitors.

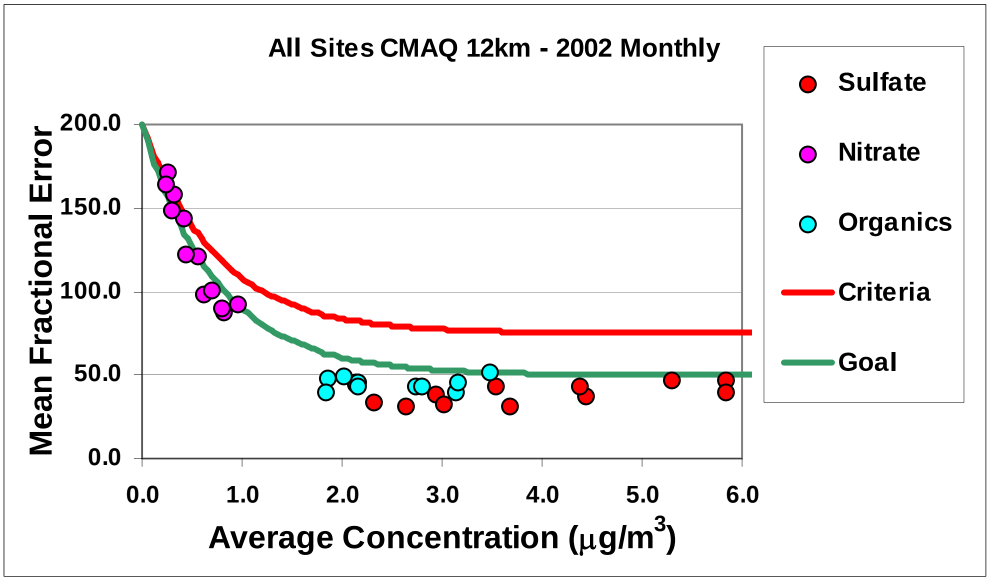


Figure 6.2-4: Bugle plot of the mean fraction bias for particulate matter and its component concentrations for all VISTAS sites.

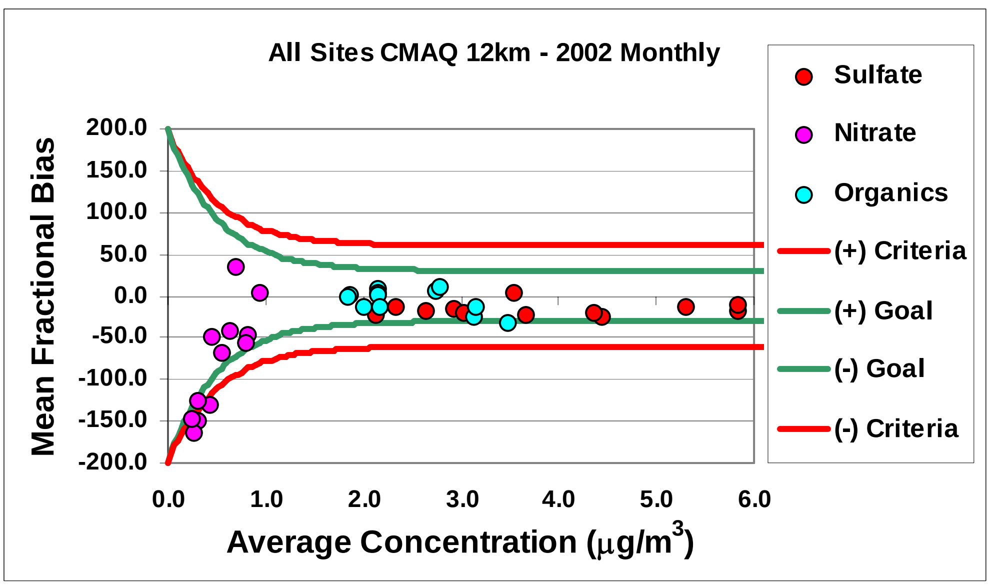


Figure 6.2-5: Bugle plot of mean fraction error for particulate matter and its component species for all VISTAS sites.

Additionally, performance assessed at the "one atmosphere" level was also deemed acceptable for ozone and particulate matter at various monitoring sites (STN, FRM, CASTNet, etc.). Overall, VISTAS found the modeling results to be representative and acceptable for use in modeling projection for ozone, particulate matter, and regional haze.

6.3 Kentucky's Class I Area Performance

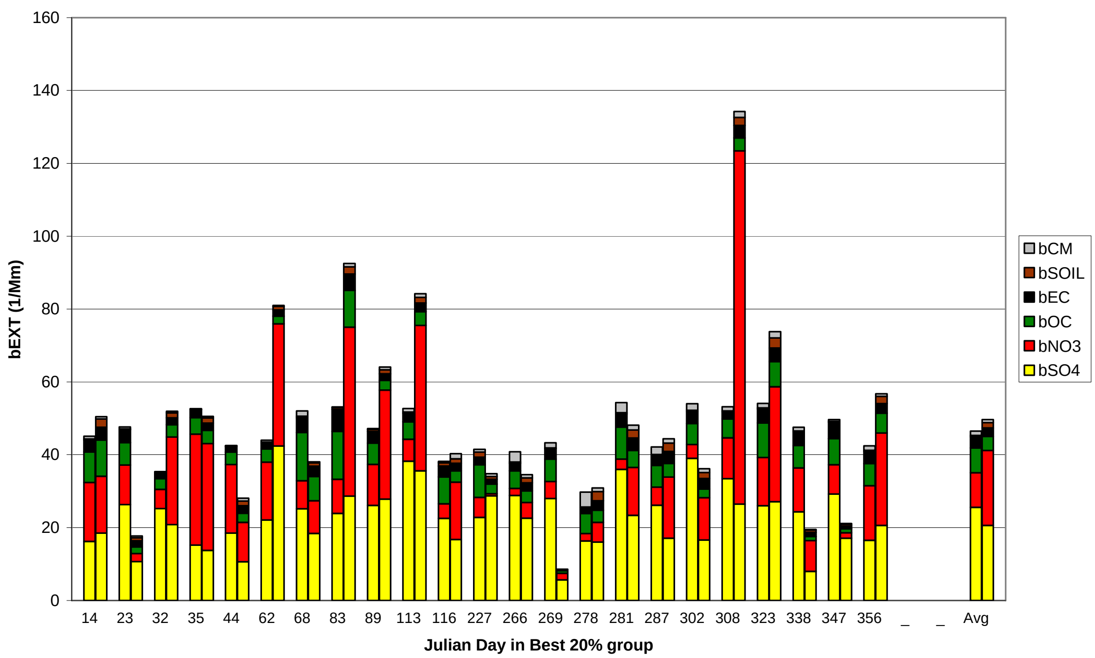
The following section provides stack bar charts comparing observed PM2.5 composition and modeled PM2.5 composition. The charts have been split into two charts, with the first displaying the 20% best days followed by the chart for the 20% worst days. Stacked bar charts have been developed for the IMPROVE monitoring site relevant to Kentucky: Mammoth Cave National Park (for the location of this area see Figure 1.4-1).

The stacked bar chart allows a side by side comparison of the each day's observed and modeled compositional and total light extinction. Within each bar the color codes are:

- Yellow = light extinction due to sulfates (bextSO4)
- Red = light extinction due to nitrates (bextNO3)
- Green = light extinction due to organic carbon (bextOC)
- Black = light extinction due to elemental (bextEC)
- Brown = light extinction due to soil (bextSoil)
- Grey = light extinction due to coarse mass (bextCM)

The components are presented in the same order for both the observed (left hand bar) and modeled bar (right hand bar), so it easy to identify days when the prediction light extinction for the component differs from the observed. The total height of the bar provides the total reconstructed particulate matter light extinction value.

Best 20% Obs (left) vs 2002gt2a (right) at MACA1



Worst 20% Obs (left) vs 2002gt2a (right) at MACA1

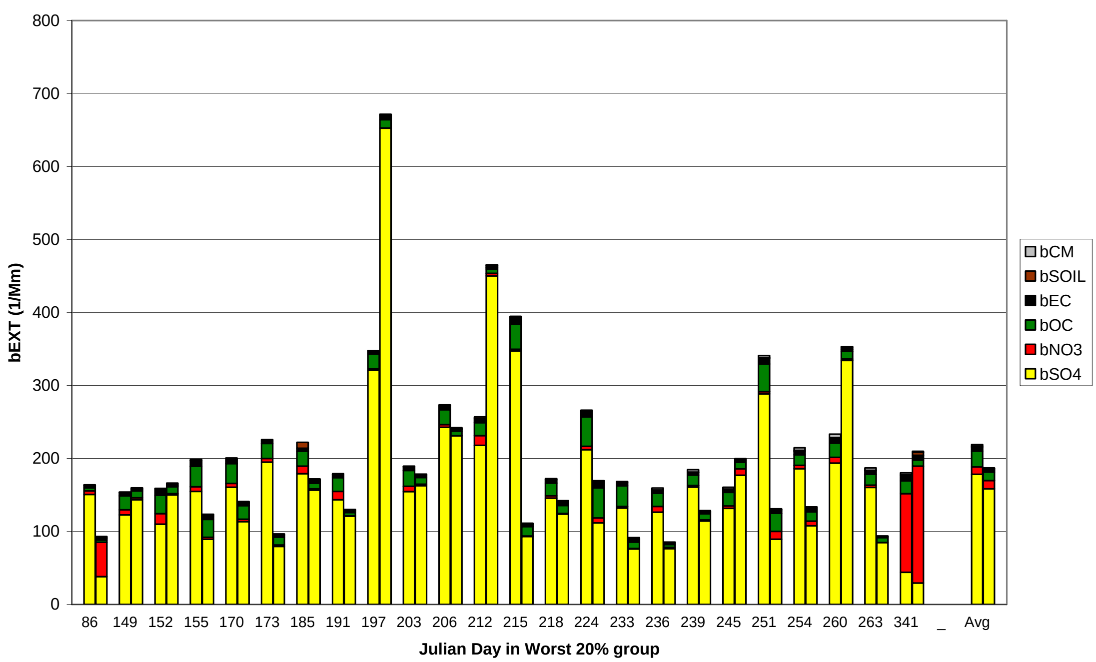


Figure 6.3-1: Stacked bar chart for Mammoth Cave on the 20% best days (top) and 20% worst days (bottom). Observed composition is presented in the left hand bar, with modeled composition represented by the right hand bar.

A cursory view of the stacked bars charts reiterates that sulfates are a large contributor to light extinction in the Kentucky Class I area on both 20% best days and 20% worst days. The bar charts also suggest that organic carbon and nitrates are important on the 20% best days at the IMPROVE site at Mammoth Cave for Kentucky**.** The bar charts for the 20% best days indicate an over prediction of the nitrate and a slight under prediction of the sulfate on many of the 20% best days.

Comparing the 20% best day charts to the 20% worst days charts, one notices that the various components of particle pollution play a more prominent role in the 20% best days than with the 20% worst days. Also, the species make up on the 20% best days varies more widely compared to the 20% worst days. This suggests accurately modeling each species is especially important on the 20% best days.

With the bar chart for the 20% worst days, you can see model performance does improve across the sites. Light extinction due to sulfate prediction is better, but still falls short on some days. Light extinction due to organic carbon also becomes more important to total light extinction. Much like the sulfate component, the organic carbon component accuracy has improved performance over the 20% best day series, thought some days are still under predicted. Overall, the KYDAQ found model performance to fall within acceptable limits for model performance. The KYDAQ further asserts the one atmosphere modeling performed by the VISTAS contractors is representative of conditions in the southeastern states and is applicable for use in attainment demonstrations.

7.0 LONG-TERM STRATEGY FOR KENTUCKY'S CLASS I AREA

As stated in Section 1.3, the regional haze rule requires a State to establish reasonable progress goals for Class I areas within the State, expressed in deciviews, that provide for reasonable progress toward achieving natural visibility by 2064. This first set of reasonable progress goals must be met through measures contained in the State's long-term strategy covering the period from the baseline through 2018. States are also to evaluate the effects of emissions from their State on Class I areas in other states. This section discusses development of Kentucky's long-term strategy.

7.1 Overview of the Long-Term Strategy Development Process

The process KYDAQ used to develop its long-term strategy was to address the following set of questions:

a. Assuming implementation of existing federal and state air regulatory requirements, how much visibility improvement would be expected at Kentucky's Class I area between now and 2018 compared to the area's uniform rate of progress?

b. What additional emission controls represent BART in Kentucky?

c. If additional emission reductions were needed, from what pollutants and source categories would the greatest visibility benefits be realized between the baseline and 2018?

d. Based on the pollutants identified in (c) above, determine what are the geographic locations (i.e., area of influence) for the Class I area where these emissions having the greatest impact on visibility are found?

e. What types of emissions sources do we find in those geographic locations (i.e., area of influence)?

f. Which specific individual sources in those geographic locations (i.e., area of influence) have the greatest visibility impacts at a Class I area?

g. What additional emission controls represent reasonable control measures for those sources identified in (f) above?

h. Given the additional emission reductions from BART and reasonable control measures identified, how much visibility improvement, compared to the glidepath, is expected at the Class I area in Kentucky between the baseline and 2018?

7.2 Expected Visibility Results in 2018 for Kentucky's Class I Area under existing and planned emissions controls

There are significant control programs being implemented between the baseline period and 2018. These programs are described in more detail below.

7.2.1 Federal and State Control Requirements

NOx SIP Call or state equivalent. Phase I of the NO_x SIP call applies to certain EGUs and large non-EGUs, including large industrial boilers and turbines, and cement kilns. Those states affected by the NOx SIP call in the VISTAS region have developed rules for the control of NOx emissions that have been approved by the USEPA. The NOx SIP Call has resulted in a 66 percent reduction in summertime NOx emissions from large stationary combustion sources in Kentucky.

CAIR**.** CAIR will permanently cap emissions of SO2 and NOx from EGUs in the eastern United States by 2015. When fully implemented, CAIR will reduce SO2 emissions from EGUs in these states by more than 70 percent, and NOx emissions by more than 60 percent, from 2003 levels.

One-hour ozone SIPs (Atlanta / Birmingham / Northern Kentucky). New SIPs have been submitted to the USEPA to demonstrate attainment of the one-hour ozone NAAQS. These SIPs require NOx reductions from specific coal fired power plants and address transportation plans in these cities.

Heavy Duty Diesel (2007) Engine Standard (for on-road trucks and buses). The USEPA set a PM emissions standard for new heavy-duty engines of 0.01 grams per brake-horsepower-hour (g/bhp-hr), to take full effect for diesel engines in the 2007 model year. This rule also includes standards for NOx and non-methane hydrocarbons (NMHC) of 0.20 g/bhp-hr and 0.14 g/ bhp-hr, respectively. These NOx and NMHC standards will be phased in together between 2007 and 2010, for diesel engines. Sulfur in diesel fuel must be lowered to enable modern pollution-control technology to be effective on these trucks and buses. The USEPA requires a 97 percent reduction in the sulfur content of highway diesel fuel from its previous level of 500 parts per million (low sulfur diesel, or LSD) to 15 parts per million (ultra-low sulfur diesel, or ULSD).

Tier 2 Tailpipe (On-road vehicles). The USEPA mobile source rules include the Tier 2 fleet averaging program, modeled after the California LEV II standards. Manufacturers can produce vehicles with emissions ranging from relatively dirty to zero emissions, but the mix of vehicles a manufacturer sells each year must have average NOx emissions below a specified value. Tier 2 standards became effective in the 2005 model year.

Large Spark Ignition and Recreational Vehicle Rule. The USEPA has adopted new standards for emissions of NOx, hydrocarbons, and carbon monoxide from several groups of previously unregulated nonroad engines. Included in these are large industrial spark-ignition engines and recreational vehicles. Nonroad spark-ignition engines are those powered by gasoline, liquid propane gas, or compressed natural gas rated over 19 kilowatts (kW) (25 horsepower). These engines are used in commercial and industrial applications, including forklifts, electric generators, airport baggage transport vehicles, and a variety of farm and construction applications. Nonroad recreational vehicles include snowmobiles, off-highway motorcycles, and all-terrain-vehicles. These rules were initially effective in 2004 and will be fully phased-in by 2012.

Nonroad Diesel Rule. This rule sets standards that will reduce emissions by more than 90 percent from nonroad diesel equipment, and reduce sulfur levels by 99 percent from current levels in nonroad diesel fuel starting in 2007. This step will apply to most nonroad diesel fuel in 2010 and to fuel used in locomotives and marine vessels in 2012.

Industrial Boiler/Process Heater/RICE MACTs. The USEPA issued final rules to substantially reduce emissions of toxic air pollutants from industrial, commercial and institutional boilers, process heaters and from stationary reciprocating internal combustion engines (RICE). These rules reduce emissions of a number of toxic air pollutants, including hydrogen chloride, manganese, lead, arsenic and mercury by 2009. This rule also reduces emissions of SO2 and PM in conjunction with the toxic air pollutant reductions. The applied Maximum Achievable Control Technology (MACT) control efficiencies were 4 percent for SO_2 and 40 percent for PM10 and PM2.5. The USEPA’s industrial boiler MACT rules were vacated on June 8, 2007. The VISTAS states decided to leave these controls in the modeling since it is believed that by 2018 the USEPA will have re-promulgated a boiler MACT rule or states will have addressed the issue through state rule making.

Combustion Turbine MACT. The projection inventories do not include the NOx co-benefit effects of the MACT regulations for Gas Turbines or stationary Reciprocating Internal Combustion Engines, which the USEPA estimates to be small compared to the overall inventory.

VOC 2-, 4-, 7-, and 10-year MACT Standards. Various point source MACTs and associated emission reductions were implemented. Reductions occurring before 2002 were assumed to be accounted for in the 2002 base year inventory.

Consent Agreements. Under a settlement agreement, by 2008, Tampa Electric will install permanent emissions-control equipment to meet stringent pollution limits; implement a series of interim pollution-reduction measures to reduce emissions while the permanent controls are designed and installed; and retire pollution emission allowances that Tampa Electric or others could use, or sell to others, to emit additional NOx, SO2, and PM.

Virginia Electric and Power Co. (VEPCO) agreed to spend $1.2 billion by 2013 to eliminate 237,000 tons of SO2 and NOx emissions each year from eight coal-fired electricity generating plants in Virginia and West Virginia.

A 2002 agreement calls for Gulf Power to upgrade its operation to cut NOx emission rates by 61 percent at its Crist generating plant by 2007, with major reductions beginning in early 2005. The Crist plant is a significant source of NOx emissions in the Pensacola area.

East Kentucky Power Cooperative (EKPC), a coal-fired electric utility, has agreed to spend approximately $650 million on pollution controls and pay a $750,000 penalty to resolve violations of the Clean Air Act at its three plants in Kentucky known as Spurlock, Dale, and Cooper. The agreement will reduce harmful air pollutants by more than 60,000 tons per year according to EPA. The company will install state-of-the-art pollution control equipment to reduce emissions of pollutants that cause acid rain and smog. The controls will reduce annual emissions of smog-forming nitrogen oxides by approximately 8,000 tons and sulfur dioxide by more than 54,000 tons per year from EKPC's Spurlock, Dale, and Cooper plants when the controls are fully implemented. This consent decree will facilitate that SO2 scrubbers are installed for EKPC's Spurlock Units 1 and 2 and Cooper Units 1 and 2 for BART. Per IPM, SO2 scrubbers for EKPC Spurlock Units 1 and 2 and Cooper Unit 2 have been included in this SIP's regional haze modeling results for 2018.

American Electric Power (AEP) has agreed to cut 813,000 tons of air pollutants annually (654,000 tons of SO2 and 159,000 tons of NOx) at an estimated cost of more than $4.6 billion, pay a $15 million penalty, and spend $60 million on projects to mitigate the adverse effects of its past excess emissions. The agreement imposes caps on emissions of pollutants from 16 plants located in five states. The facilities are located in Moundsville (2 facilities), St. Albans, Glasgow, and New Haven (2 facilities), West Virginia; Louisa, Kentucky; Glen Lyn and Carbo, Virginia; Brilliant, Conesville, Cheshire, Lockburne, and Beverly, Ohio; and Rockport and Lawrenceburg, Indiana. AEP will install pollution control equipment to reduce and cap sulfur dioxide and nitrogen oxide emissions by more than 813,000 tons per year when fully implemented. By installing these pollution control measures, the plants will emit 79 percent less sulfur dioxide and

69 percent less nitrogen oxides, as compared to 2006 emissions. This consent decree will facilitate that a SO2 scrubber is installed for Kentucky's AEP Big Sandy Unit 2 for BART. Per IPM, a SO2 scrubber for AEP Big Sandy Unit 2 has been included in this SIP's regional haze modeling results.

7.2.2 Additional State programs to reduce emissions

In addition to accounting for specific emission reductions due to ongoing air pollution programs as required under the regional haze rule section 308 (d)(3)(v)(A), states are also required to consider the air quality benefits of measures to mitigate the impacts of construction activities [section 308(d)(3)(v)(B)] and agricultural and forestry smoke management [section 308(d)(3)(v)(E)]. These state measures are discussed in more detail in Appendix H.

7.2.3 Projected 2009 and 2018 Emissions Inventories

The inventories for 2009 and 2018 account for post-2002 emission reductions from promulgated and proposed federal, state, local, and site-specific control programs as of July 1, 2004. In general, emissions inventories were developed for 2009 and 2018 using current control information in Kentucky.

For EGUs, IPM results were adjusted based on state and local air agencies knowledge of planned emission controls at specific EGUs. These updates are documented in the MACTEC emissions inventory report "Documentation of the 2002 Base Year and 2009 and 2018 Projection Year Emission Inventories for VISTAS" dated February 2007 (Appendix D).

For non-EGUs, VISTAS used recently updated growth and control data consistent with the data used in the USEPA's CAIR analyses (Clean Air Interstate Rule Emissions Inventory Technical Support Document, March 2005) supplemented by state and local air agencies data and updated forecasts from the Department of Energy (DOE).

Area source controls were estimated using known state level Stage I controls on gasoline dispensing facilities and open burning estimates, as well as controls used to project emissions for the USEPA's Heavy Duty Diesel rulemaking and for the CAIR rulemaking.

Mobile source controls included local controls underlying the 2002 baseline inventory (vehicle emission inspection, Stage II vapor recovery, anti-tampering, etc.) with changes based on specific State input. The future year inventories were developed by running the MOBILE6.2 model for each year modeled. The future year emissions for the off-road mobile sources included in the USEPA NONROAD model were estimated by running the model for each future year. For the other off-road mobile source categories control data and projections for 1996, 2010, 2015, and 2020 were obtained from the USEPA's CAIR Technical Support Document, and straight-line projections were used to estimate 2009 and 2018 levels.

The following bar charts show expected decreases in emissions of SO2 and NOx across the VISTAS states from 2002 through 2018. (Similar charts for other visibility impairing pollutants are contained in Appendix H). Note that for SO2 emissions in particular, which are the largest contributors to haze, emissions from electric generating facilities are expected to decrease dramatically (70 percent) between 2002 and 2018. However, even after implementation of CAIR, EGU emissions are projected to remain the largest contributor to haze, comprising more than half of remaining SO2 emissions in most states.

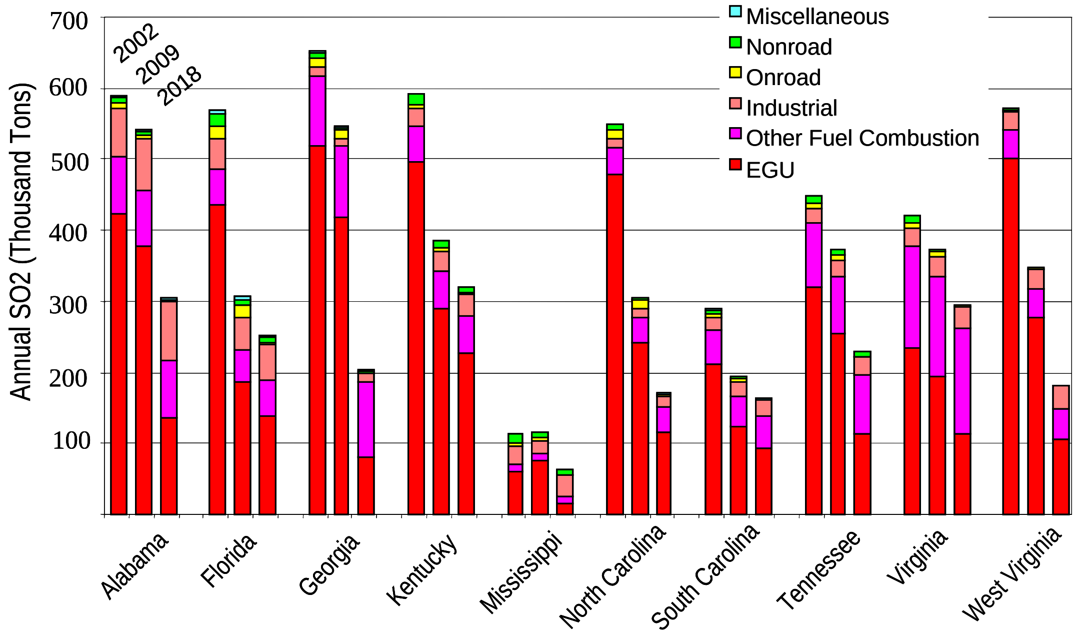


Figure 7.2.3-1. Annual SO2 emissions for 2002, 2009, and 2018 in the VISTAS states

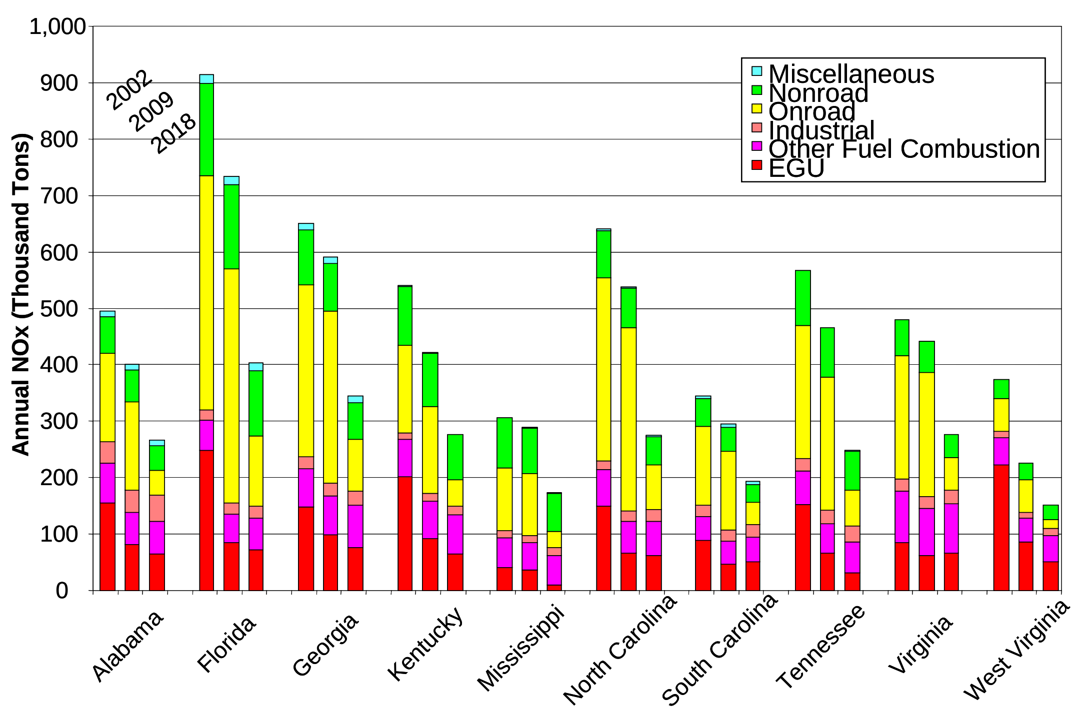


Figure 7.2.3-2. Annual NOx emissions for 2002, 2009, and 2018 in the VISTAS states

Summary of Emission Inventories for 2002, 2009, and 2018

Tables 7.2.3-1, 7.2.3-2, and 7.2.3-3 are summaries of the 2002, 2009, and 2018 emission inventory, respectively. The complete inventory and discussion of the methodology is contained in Appendix D.

Table 7.2.3-1. 2002 Emissions Inventory Summary for Kentucky (tons per year).

	VOC	NOx	PM2.5	PM10	NH3	SO2
Point	46,315	240,362	14,219	21,421	995	529,182
Area	98,713	40,966	51,763	240,226	51,246	41,941
On-Road Mobile	103,503	156,417	2,697	3,723	5,055	6,308
Non-Road Mobile	44,805	104,571	6,046	6,425	31	14,043
Biogenics	630,506	21,090	0	0	0	0
TOTAL	923,842	563,406	74,725	271,795	57,327	591,474

Table 7.2.3-2. 2009 Emissions Inventory Summary for Kentucky.

	VOC	**NOx**	**PM2.5**	**PM10**	**NH3**	**SO2**
Point	49,154	129,778	15,966	23,637	1,160	326,611
Area	97,379	43,548	52,553	248,844	53,115	43,222
On-Road Mobile	73,942	101,182	1,920	2,976	5,796	759
Non-Road Mobile	38,558	94,752	5,203	5,544	34	9,180
Biogenics	630,506	21,090	NA	NA	NA	NA
TOTAL	889,539	390,350	75,642	281,001	60,105	379,772

Table 7.2.3-3. 2018 Emissions Inventory Summary for Kentucky.

	VOC	**NOx**	**PM2.5**	**PM10**	**NH3**	**SO2**
Point	57,287	105,411	18,172	26,848	1,377	266,745
Area	106,827	45,806	53,955	262,719	55,321	44,322
On-Road Mobile	47,066	52,263	1,272	2,580	7,811	763
Non-Road Mobile	30,920	79,392	4,256	4,556	40	8,592
Biogenics	630,506	21,090	NA	NA	NA	NA
TOTAL	872,606	303,962	77,655	296,703	64,549	320,422

7.2.4 Model Results for the 2018 Inventory Compared to the Uniform Rate of Progress Glidepaths for Kentucky's Class I Area

Using 2000 - 2004 IMPROVE monitoring data, the deciview values for the 20 percent best days in each year are averaged together, producing a single average deciview value for the best days. Similarly, the deciview values for the 20 percent worst days in each year are averaged together, producing a single average deciview value for the worst days. The average values represent the current visibility conditions.

The predicted visibility improvement is calculated by comparing the 2002 typical year modeling results for the 12-km grid to the 2018 12-km modeling results to develop a relative reduction factor. This factor is then applied to the current visibility condition values to estimate the future visibility. Detailed discussions about how the relative reduction factors are calculated can be found in Appendix G.

For the 20% worst days in Kentucky's Class I area, Figure 7.2.4-1 graphically compares the visibility which would result with the area's uniform rate of progress (red line) to the predicted visibility from 2004 to 2018 due to modeled emission reductions expected by federal and state control programs (purple line) Similarly, for the 20% best days in the area, Figure 7.2.4-2 graphically compares visibility with no degradation over the first planning period (red line) to the predicted visibility from 2004 to 2018 due to modeled emission reductions expected by federal and state programs (purple line).

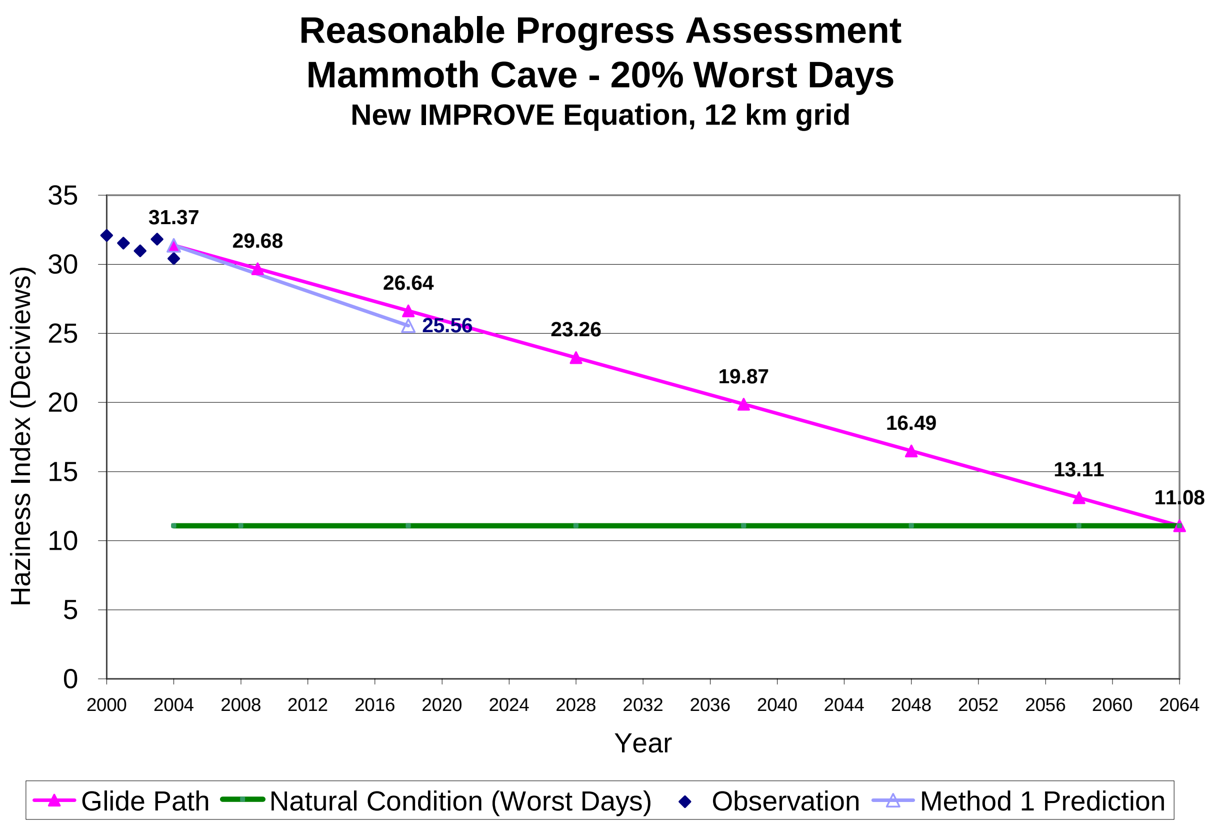


Figure 7.2.4-1. Reasonable progress assessment compared to Uniform Rate of Progress for 20% worst days at Mammoth Cave National Park.

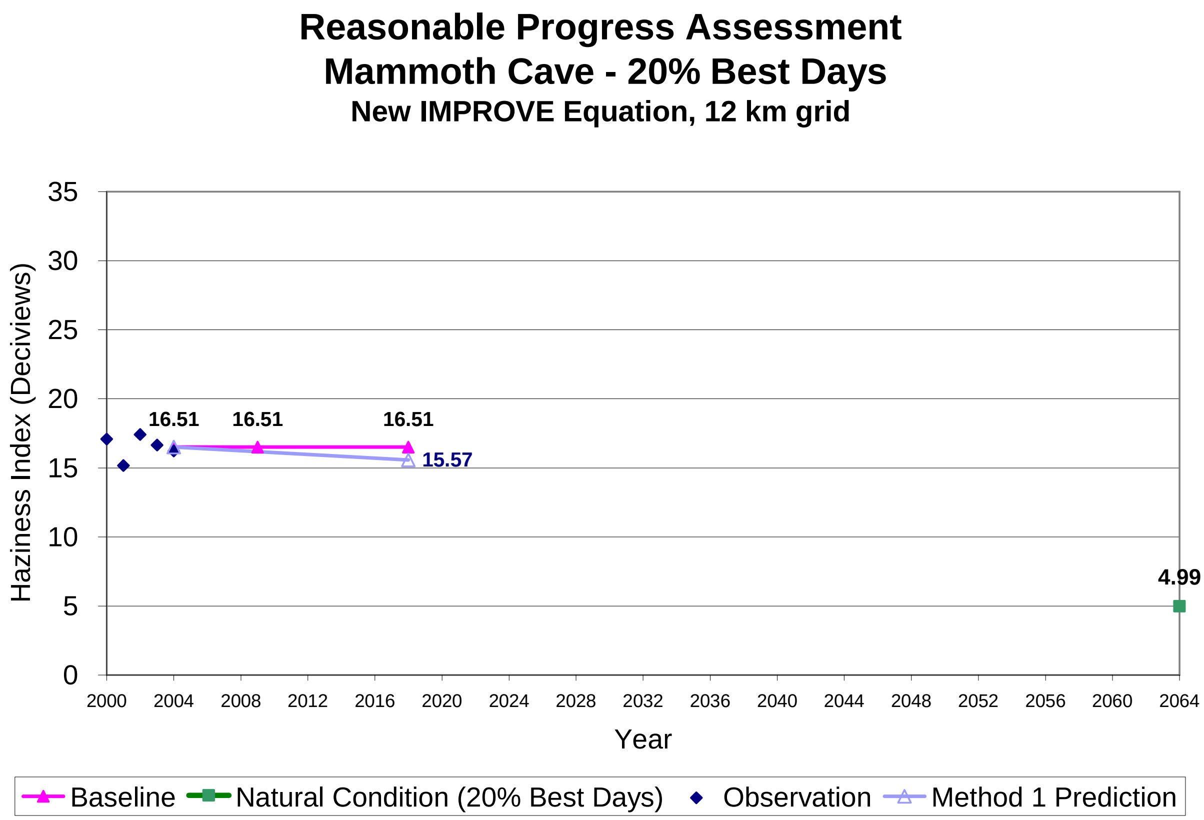


Figure 7.2.4-2 Reasonable progress assessment for 20% best days at Mammoth Cave NP.

Note that for Mammoth Cave, visibility improvements on the 20 percent worst days are expected to be better than the uniform rate of progress glidepath by 2018 based solely on reductions from existing and planned emissions controls**.** For Mammoth Cave, a 4.73 dv improvement in visibility would meet uniform rate of progress in 2018; expected emissions reductions by 2018 are projected to achieve a 5.81 dv improvement. In fact, as illustrated in Figure 7.2.4-3, visibility improvements at all the VISTAS mountain Class I areas and most of the coastal Class I areas are projected to be better than the uniform rate of progress. In Figure 7.2.4-3 the percentage of the target reduction achieved for Kentucky's Class I area using the new IMPROVE equation is an estimated 123 percent. This means that the rate of improvement is 23 percent greater than the uniform rate of progress by 2018.

In addition to improving visibility on the 20 percent worst visibility days, states are also required to protect visibility on the 20 percent best days at the Class I areas. As illustrated in Figure 7.2.4-4, visibility on the 20 percent best days is projected to improve in 2018 at all VISTAS Class I areas as a result of the 2018 emission reductions. In Figure 7.2.4-4 the percentage of the target achieved for the Kentucky's Class I area is an about -6 percent. Zero percent change would mean no change in visibility; -6 percent means that visibility is better than no change, or a 6 percent improvement (values lower than current conditions).

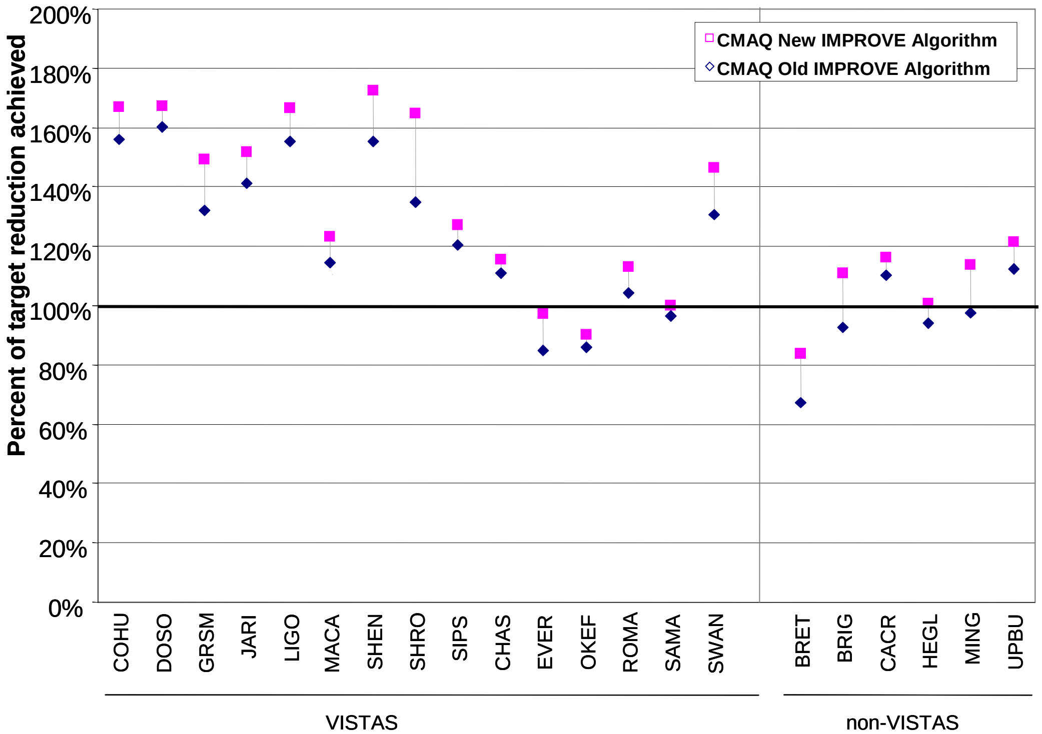


Figure 7.2.4-3. Projected visibility improvement on 20 percent worst visibility days at VISTAS and neighboring Class I areas for 2018 (12 km grid)

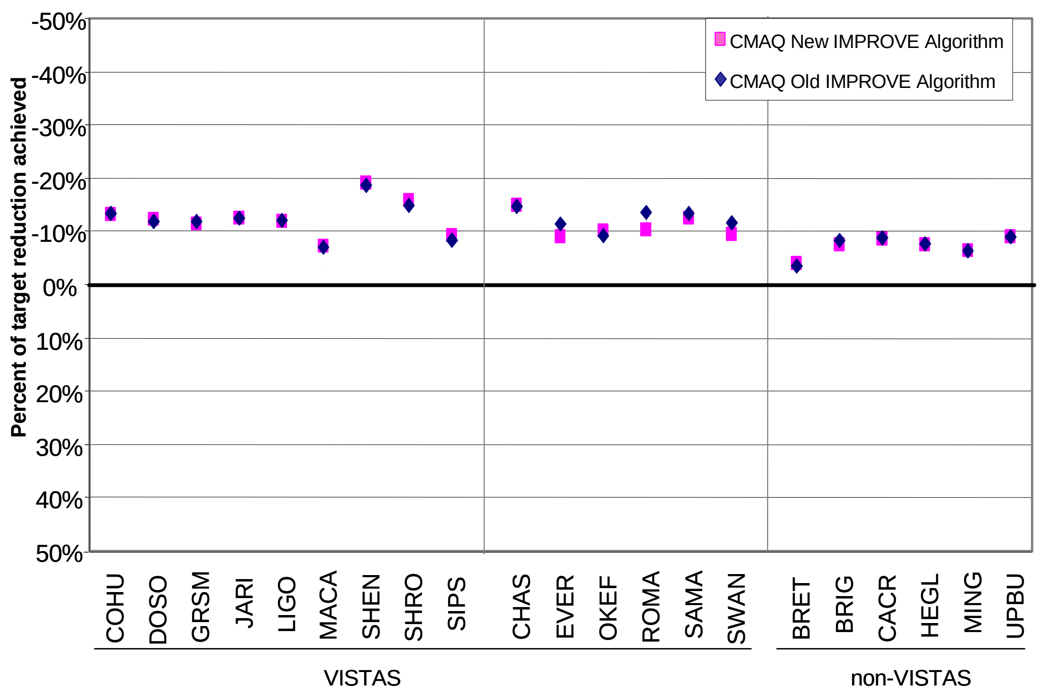


Figure 7.2.4-4. Projected visibility improvement on 20 percent best visibility days at VISTAS and neighboring Class I areas for 2018 (12 km grid)

The expected change in visibility at Mammoth Cave between 2000-2004 baseline conditions on the 20 percent worst days and 2018 projections is illustrated in Figure 7.2.4-5. In contrast, natural background visibility conditions for the 20 percent worst days are illustrated at Mammoth Cave in Figure 7.2.4-6. These images were generated using WINHAZE, a photographic imaging tool that accounts for the effect of concentrations of fine particle components and relative humidity on visibility. These images try to illustrate that notable improvements in visibility are expected by 2018 and that significantly greater improvements are needed to reach natural background conditions.

20% Haziest Days at Mammoth Cave

Figure 7.2.4-5. Visibility improvement on 20 percent haziest days at Mammoth Cave National Park between 2000-2004 baseline conditions (left) and 2018 projected visibility (right). Image generated using WinHaze.

Natural Background Visibility at Mammoth Cave

Figure 7.2.4-6. Projected visibility on 20 percent haziest days for natural background visibility conditions at Mammoth Cave National Park. Image generated using WinHaze.

7.3 Relative Contribution from International Emissions to Visibility Impairment in 2018 at VISTAS Class I areas

Emissions from Mexico, Canada, Central America, Asia, and Africa contribute to PM2.5 loadings and visibility impairment at Class I areas in the continental United States. To evaluate the relative contribution of international emissions to visibility at Class I areas in the southeastern United States, VISTAS used a combination of modeling results from the global three-dimensional chemical transport model (GEOS-Chem) and CMAQ. VISTAS used the GEOS-Chem global model to generate initial and boundary conditions for the CMAQ modeling domain. GEOS-Chem was run for the 2002 modeling year using a 4 x 5 degree horizontal grid resolution and a 3-hour temporal resolution. Because emissions were based on monthly averages, the model does not capture the episodic variability in emissions. The GEOS-Chem outputs were used to calculate initial and boundary conditions for the national CMAQ modeling domain. The national CMAQ domain included portions of Canada and Mexico, so emissions for these countries were included within the national CMAQ modeling domain or as part of the boundary conditions outside the national modeling domain, as appropriate.

Two complementary methods were used to calculate the impact of international emissions at Class I areas. Because the international emissions inventory used in GEOS-CHEM did not distinguish between wildfires and anthropogenic fires, all international fire emissions were assumed to be wildfire, and the contributions attributable to international anthropogenic fires are underestimated in these projections.

1) International emissions are represented by the difference between two GEOS-Chem runs. In the first run United States anthropogenic emissions were removed, and in the second run both United States and international anthropogenic emissions were removed. The difference represents international anthropogenic emissions, in the absence of United States anthropogenic emissions (e.g. compared to 2064 levels). Harvard University provided GEOS-Chem results to VISTAS for 2002 international contribution on 4 x 5 degree grid. Concurrently Harvard modeling for the Electric Power Research Institute (EPRI) provided GEOS-Chem results for 2001 international contribution on a 1 x 1 degree grid scale.

2) International emissions are represented by the difference between two CMAQ 36-km simulations, both using 2018 Base F emissions and boundary conditions from GEOS-Chem. In the first CMAQ run, all global natural and anthropogenic emissions in 2018 are active. In the second CMAQ run, only global (United States and international) natural emissions are active. Here the impacts of international emissions are compared against 2018 conditions rather than natural background conditions.

VISTAS has compared its results to results from other RPOs on the impact of international emissions and boundary conditions on visibility at Class I areas in 2002; the results were similar.

As illustrated in Figure 7.3-1 for annual average contributions to sulfate at VISTAS and neighboring Class I areas, the estimated international contributions are higher at Class I areas near the Canadian and Mexican borders and along the eastern coast. The estimated international contribution is higher using CMAQ than in the GEOS-Chem runs because the grid scale is finer (more accurate dispersion of emissions) and because the background atmosphere includes loadings from current United States anthropogenic emissions (greater photochemical activity). Similar charts for nitrate and organic carbon mass, for impacts on 20 percent worst visibility days, and for impacts of international emissions on calculated light extinction are included in Appendix H.

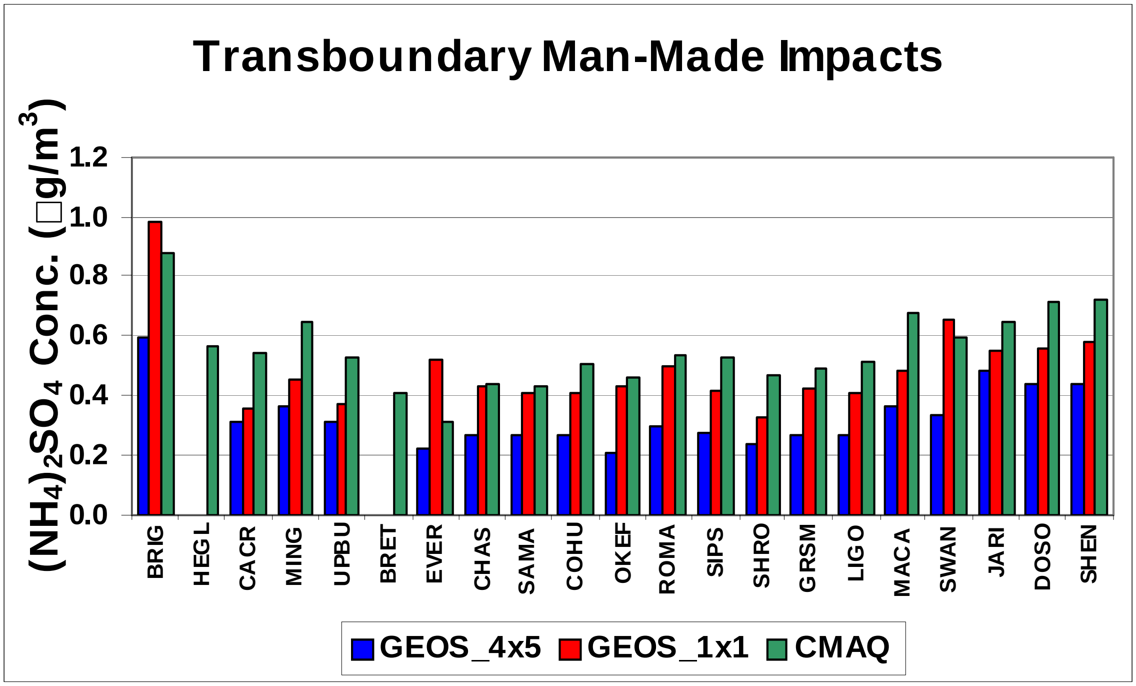


Figure 7.3-1. Estimated international emissions contributions to sulfate at VISTAS and neighboring Class I areas.

In Figure 7.3-2 CMAQ projections of contributions from international emissions to PM mass on 20 percent worst visibility days in 2002 at Mammoth Cave, Kentucky are compared to United States domestic contributions to PM components at the site on those days.

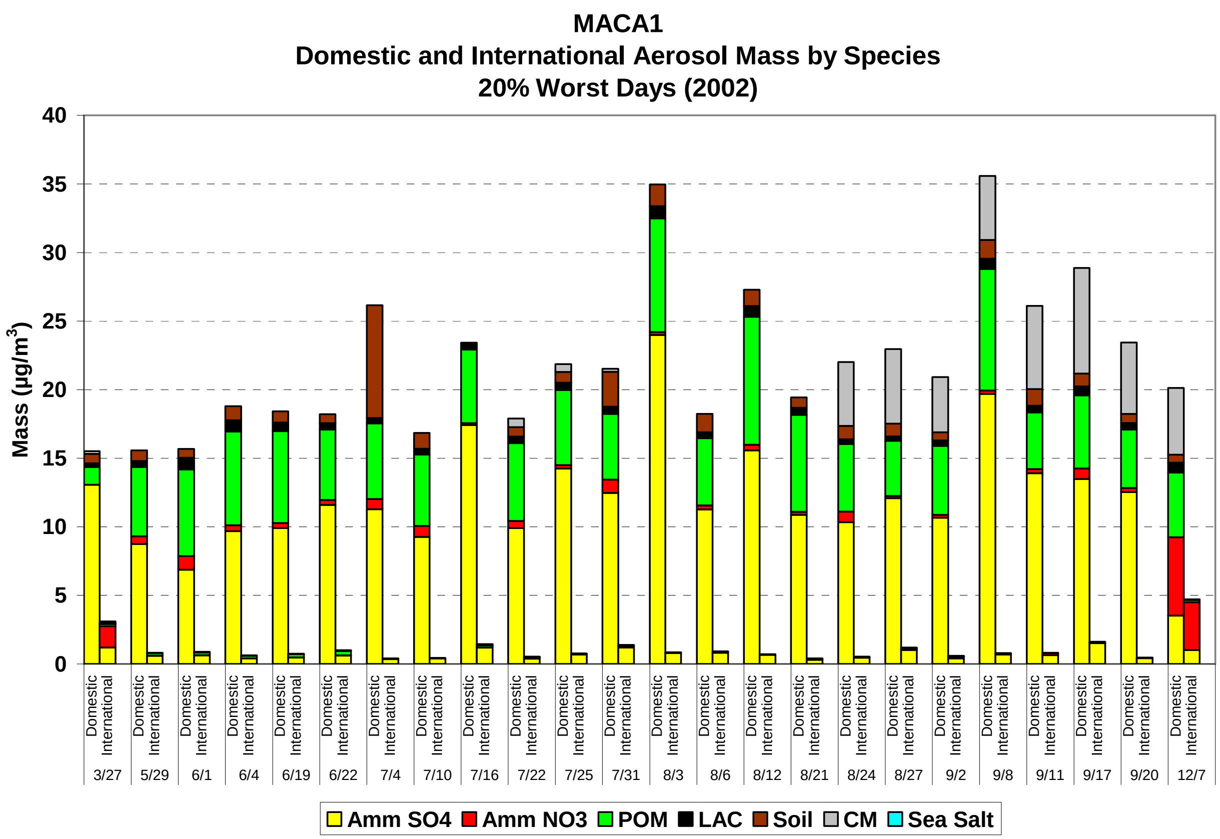


Figure 7.3-2. PM component concentrations from US domestic sources on 20 percent worst visibility days in 2002 (left bars) and CMAQ-simulated international contributions (right bars) at Mammoth Cave, Kentucky.

Although VISTAS assessed impacts from international emissions at the Class I areas, these modeling runs were to provide information to the states to understand what the potential impacts may be at their Class I areas. The modeling showed that for Kentucky's Class I area Mammoth Cave the impacts from international emissions were 1.27 dv of the projected current conditions. Since good projected emissions for areas outside of the continental United States are not readily available, there is no real way to assess what the impacts from international emissions would be for 2018, other than to assume that it would be approximately same amount as for the baseline current conditions. Therefore, the KYDAQ will not be accounting for international emissions in setting the 2018 reasonable progress goals for its Class I areas.

Nevertheless, as the atmosphere becomes closer to natural background conditions in the future, the incremental contribution from international emissions will become more important. The information is included in this SIP documentation to provide reference for future assessments of reasonable progress.

7.4 Relative Contributions to Visibility Impairment: Pollutants, Source Categories, and Geographic Areas

An important step toward identifying potential reasonable control measures is to identify the key pollutants contributing to visibility impairment at each Class I area. To understand the relative benefit of further reducing emissions from different pollutants, source sectors, and geographic areas, VISTAS engaged the Georgia Institute of Technology to perform emission sensitivity model runs using CMAQ. Emissions sensitivities were initially performed for three episodes representing winter and summer conditions: Jan 2002, July 2001, and July 2002. These runs used the initial 2018 projections inventory and considered 30 percent reductions from specific pollutants, source categories, and geographic areas. As part of a separate effort, emissions sensitivities were repeated using a preliminary 2009 projection inventory and two, month-long episodes from 2002: Jun 1 – Jul 10 and Nov 19 – Dec 19. The emissions in 2009 were reduced by 30 percent for each pollutant sensitivity run. The pollutant contributions that were evaluated were:

- SO2 from EGU sources in each VISTAS state, other RPOs in the VISTAS 12 km grid, and Boundary Conditions from outside the 12 km domain.
- SO2 from non-EGU point sources in each VISTAS state, other RPOs, and Boundary Conditions
- NOx from ground level sources (on-road plus off-road plus area) in each VISTAS state and other RPOs. In the VISTAS states, these reductions were only applied to specific counties that were of concern for 8-hour ozone nonattainment.
- NOx from point (EGU plus non-EGU) sources in each VISTAS state and other RPOs
- NH3 from all sources in VISTAS and other RPOs
- Volatile Organic Compounds from anthropogenic and biogenic sources in the 12 km modeling domain
- Primary Carbon from all ground level sources in each VISTAS state and other RPOs. In the VISTAS states, these reductions were only applied to specific counties that were of concern for PM2.5 nonattainment.
- Primary Carbon from all point sources in each VISTAS state and other RPOs
- Primary Carbon from all fires in each VISTAS state and other RPOs

While the 2009 sensitivity analyses cannot be used to judge the absolute contributions from each state or source sector, the results do indicate relative level of response among pollutants, sectors, and geographic areas. The KYDAQ decided to use the 2009 sensitivities to assess relative contribution to visibility impairment from various source sectors and believes this is an appropriate use of this data since the use of the emissions sensitivities is to qualitatively understand how reductions in emissions from various source sectors would impact visibility at Class I areas.

Results are shown in Figures 7.4-1 below for the average of the 20 percent worst visibility days for Kentucky’s Class I area. Responses for 20 percent worst days were calculated by averaging the responses of the 20 percent worst days that were modeled in the two episodes. For Kentucky's site, responses on six of the 20 percent worst visibility days were included in these graphics.

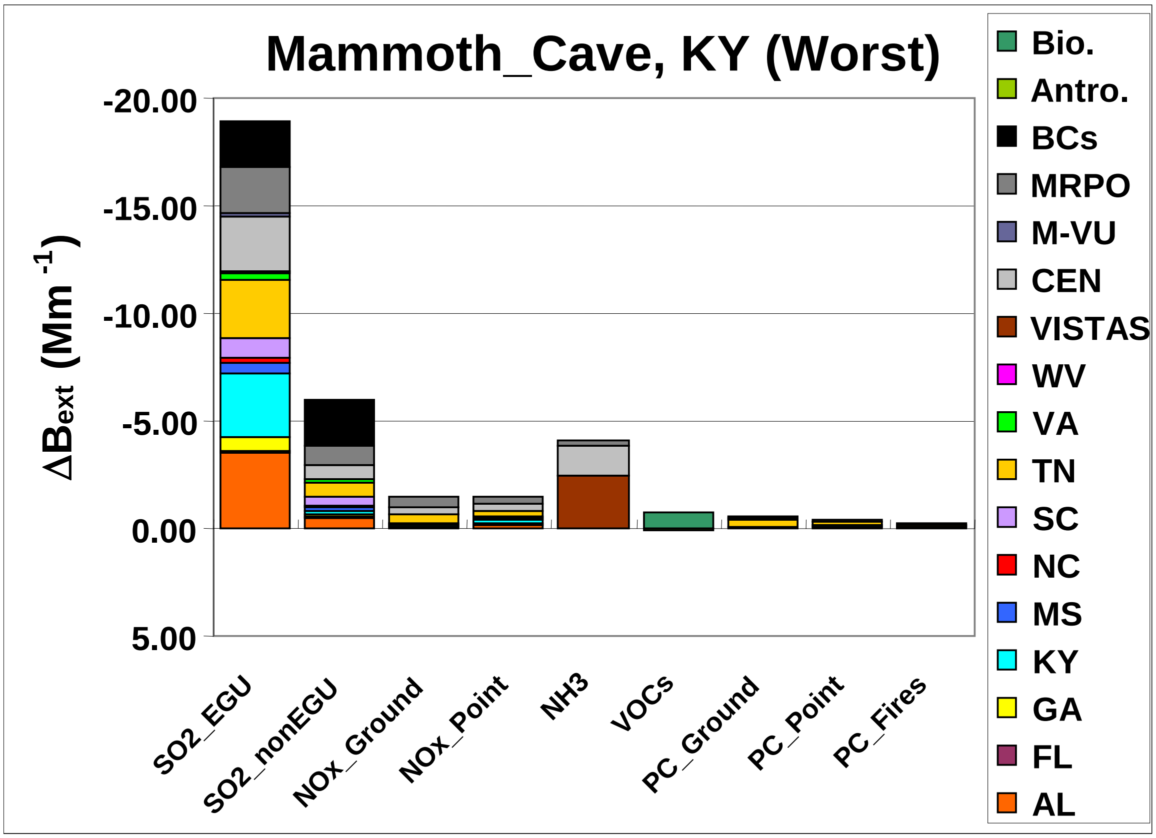


Figure 7.4-1. CMAQ projections of visibility responses on 20 percent worst days at Mammoth Cave to 30 percent reductions from a 2009 inventory for visibility-reducing pollutants in different source categories and geographic areas.

As Figure 7.4-1 illustrates, the greatest visibility benefits on the 20 percent worst days for the Kentucky's Class I area are projected to result from further reducing SO2 from EGUs. At the mountain Class I areas, benefits are projected from SO2 reductions from EGUs in several VISTAS states including Alabama, Georgia, Kentucky, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia. Contributions from other RPOs and SO2 coming from outside the boundary are also significant. The greatest benefit would likely be from further reductions from other VISTAS states, the MRPO, and outside the boundary. Additional, smaller benefits are projected from additional SO2 emission reductions from non-utility, industrial point sources. The pattern of relative SO2 contributions from non-EGUs among the various VISTAS states is similar to the pattern of relative SO2 contributions from EGUs.

Because ammonium nitrate is a small contributor to PM2.5 mass and visibility impairment on the 20 percent worst days at the mountain Class I areas, the benefits of reducing NOx and NH3 emissions at these sites are small.

VOC emissions do contribute to visibility impairment, but as shown in the charts above, this contribution is from biogenic sources such as vegetative emissions. Controlling anthropogenic sources of VOC emissions has little if any visibility benefit at the Class I areas. Reducing primary carbon from point sources, ground level sources or fires are projected to have small to no visibility benefit. This is consistent with the monitoring data that shows that most of measured organic carbon is secondary in origin and primary carbon is only a small fraction of the total measured carbon (Appendix B). Reducing carbon from fires was not found to be effective because there was little fire activity at these sites on the days modeled in the sensitivity analyses.

Note that these results from the emission sensitivity runs are consistent with the conclusions drawn from the 2000-2004 baseline monitoring data (see Section 2.4). The results indicate that sulfate is the dominant contributor to visibility impairment on the 20 percent worst days at all sites, and that ammonium nitrate may be important for sites where the 20 percent worst days occur in the winter. KYDAQ concludes that reducing SO2 emissions from EGUs in the Midwest RPO would have the greatest visibility benefit for Mammoth Cave. Contributions from other VISTAS states are also significant for this area. These results are consistent with the CMAQ model results indicating that contributions from international emissions to visibility impairment at VISTAS Class I areas are greater closer to the boundaries of the modeling domain (see summary in Section 7.3 and further discussion in Appendix H).

7.5 What Control Determinations Represent Best Available Retrofit Technology for Individual Sources?

Section 169A of the CAA directs States to assess certain large emission sources for additional controls in order to address visibility impacts. States are directed to conduct BART determinations for such sources in specific source categories, and which contribute to visibility impairment in Class I areas. The 1999 regional haze rule includes the BART requirement, and directs States to include BART in their regional haze SIPs. On July 6, 2005, the USEPA published a revised final rule, including Appendix Y to 40 CFR Part 51, the *Guidelines for BART Determinations Under the Regional Haze Rule* (hereinafter referred to as the "BART Guidelines") that provides direction to states on determining which of these sources should be subject to BART, and how to determine BART for each source.

A BART-eligible source is one which has the potential to emit 250 tons or more of a visibility-impairing air pollutant, was put in place between August 7, 1962 and August 7, 1977, and whose operations fall within one or more of 26 specifically listed source categories. Under the CAA, BART is required for any BART-eligible source that a State determines ‘‘emits any air pollutant which may reasonably be anticipated to cause or contribute to any impairment of visibility in any such area.''

For those sources subject to BART, Section 169A(g)(7) of the CAA requires that States must consider the following factors in making BART determinations: (1) the costs of compliance, (2) the energy and non-air quality environmental impacts of compliance, (3) any existing pollution control technology in use at the source, (4) the remaining useful life of the source, and (5) the degree of improvement in visibility which may reasonably be anticipated to result from the use of such technology.

7.5.1 Kentucky BART-Eligible Sources

The following is a list of BART-eligible sources in Kentucky. See Appendix L for detailed information regarding each of the BART-eligible sources:

- American Electric Power Big Sandy Plant
- AK Steel Corporation. - Coke Mfg Plant
- AK Steel Corporation - Steel Plant
- Alcan Primary Products Corporation
- Arch Chemicals Inc.
- Calgon Carbon Corporation
- Century Aluminum
- Commonwealth Aluminum Lewisport LLC
- Duke Energy East Bend Station
- E.ON U.S Brown Station
- E.ON U.S Cane Run Station
- E.ON U.S Ghent Station
- E.ON U.S Mill Creek Station
- East Kentucky Power Cooperative Cooper Station
- East Kentucky Power Cooperative Spurlock Station
- Henderson Power and Light
- Marathon Petroleum Company Refinery
- Martin County Coal Corporation
- NewPage Corporation Wickliffe Paper Company
- Owensboro Municipal Utilities
- Pinnacle Processing Inc.
- TVA Paradise Plant
- Western Kentucky Energy Coleman Station
- Western Kentucky Energy Green Station
- Western Kentucky Energy Reid/Henderson Station
- Westlake Vinyls Inc.

The BART-eligible sources were identified using the methodology in the BART Guidelines.

- One or more emissions units at the facility fit within one of the 26 categories listed in the BART Guidelines;
- The emission unit(s) were in existence on August 7, 1977 and began operation at some point on or after August 7, 1962; and
- The potential emissions considering enforceable limits from all emission units identified in the previous two bullets emission units were 250 tons or more per year of any of these visibility-impairing pollutants: SO2, NOx, and PM10.

The BART Guidelines recommend addressing these visibility-impairing pollutants: SO2, NOx, and particulate matter, and suggest that States use their best judgment in determining whether to address VOC or ammonia emissions. The KYDAQ addressed SO2 and NOx, and used particulate matter less than 10 microns in diameter (PM10) as an indicator for particulate matter to identify BART-eligible units, as the BART Guidelines recommend. As discussed in detail in Appendix L, VISTAS modeling demonstrated that VOCs and ammonia from point sources are not visibility-impairing pollutants. For this reason, the KYDAQ did not evaluate emissions of VOCs and ammonia in BART determinations. Additional BART modeling information and BART related information regarding KYDAQ BART-eligible sources is available in Appendix L.

The following five KYDAQ sources were determined not to be BART-eligible based on the BART methodology in the BART Guidelines. These sources were discussed with EPA in the January 2006. Documentation and correspondence regarding these sources is available in Appendix L.

- Arkema (Formerly Atofina Chemicals)
- E.I. Dupont Inc.
- Cc Metals & Alloys Inc.
- ISP Chemicals Inc.
- Kingsford Manufacturing Co.

7.5.2 Determination of Sources Subject to BART in Kentucky

Under the BART Guidelines, the KYDAQ may consider exempting some sources from BART if it is determined that they do not cause or contribute to visibility impairment in a Class I area. In accordance with the BART guidelines, the KYDAQ chose to perform source-specific analyses to determine which sources cause or contribute to visibility impairment using the CALPUFF model. The CALPUFF modeling protocol used for determining which facilities are subject to BART is included in Appendix L. In accordance with the Guidelines, a contribution threshold of 0.5 dv was used for determining which sources were subject to BART. Detailed discussions about how a threshold of 0.5 dv meets the USEPA's BART guidelines can be found in Appendix L.

All of Kentucky's twenty-six BART-eligible sources had BART exemption-modeling demonstrations performed; nine of the sources that had Q/d of less than 10 for actual 2002 SO2 emissions had exemption modeling performed through VISTAS contractor TRC and 17 sources performed the BART exemption modeling with their own contractor. Twenty-one of the twenty-six sources were able to demonstrate exemption from BART (< 0.5 dv) either with 12 km or 4 km modeling. Results of these demonstrations are summarized in Table 7.5.2-1 as follows. Additional details are available in Appendix L. Facilities found to be subject to BART were required to complete a BART determination analysis.

Table 7.5.2-1 represents the facilities that were able to demonstrate exemption from BART based on CALPUFF modeling conducted using the VISTAS modeling protocol and either the old IMPROVE equation or new IMPROVE equation. The KYDAQ is proposing to exempt the units listed in Table 7.5.2-1. For further details about the BART exemption modeling, please refer to Appendix L.

Table 7.5.2-1. Kentucky BART Exemption Modeling Results for Sources Exempted From BART

Source	**Class I Area**	**Impact (Change in DV)**	**Modeling**
Duke Energy East Bend Station	Mammoth Cave (210 km)	0.242	12 km Max dv value
Owensboro Municipal Utilities	Mammoth Cave (93 km)	0.432	4km 8th Highest dv value
	Mingo (289 km)	0.053	4km 8th Highest dv value
AK Steel Corporation - Steel Plant	Dolly Sods (287 km)	0.346	4km Max dv value
	James River Face (295 km)	0.386	4km Max dv value
	Linville Gorge (293)	0.358	4km Max dv value
	Otter Creek (261)	0.442	4km Max dv value
	Great Smokey Mt. (308 km)	0.190	4km 8th Highest dv value
AK Steel Corp. - Coke Mfg Plant	Dolly Sods (282 km)	0.180	12 km Max dv value
	Great Smokey Mt. 1 (304 km)	0.262	12 km Max dv value
	James River Face (288 km)	0.182	12 km Max dv value
	Linville Gorge (287 km)	0.155	12 km Max dv value
	Otter Creek (257 km)	0.208	12 km Max dv value
Martin County Coal Corporation	Dolly Sods1 (305 km)	0.068	12 km Max dv value
	Great Smokey Mt. (226 km)	0.135	12 km Max dv value
	James River Face (265 km)	0.085	12 km Max dv value
	Joyce Kilmer-Slickrock (285 km)	0.121	12 km Max dv value
	Linville Gorge (207 km)	0.131	12 km Max dv value
	Otter Creek (280 km)	0.077	12 km Max dv value
	Shining Rock (259 km)	0.103	12 km Max dv value
Pinnacle Processing Inc.	Great Smokey Mt. (235 km)	0.108	12 km Max dv value
	James River Face (262)	0.070	12 km Max dv value
	Joyce Kilmer-Slickrock (294 km)	0.053	12 km Max dv value
	Linville Gorge (214 km)	0.077	12 km Max dv value
	Otter Creek (272 km)	0.015	12 km Max dv value
	Shining Rock (268 km)	0.021	12 km Max dv value
Arch Chemicals Inc.	Mammoth Cave (83 km)	0.417	4km 8th Highest dv value
Commonwealth Aluminum Lewisport LLC	Mammoth Cave (94 km)	0.489	12 km Max dv value
	Mingo (304 km)	0.052	12 km Max dv value
Henderson Power and Light	Mammoth Cave (134 km)	0.302	12 km Max dv value
	Mingo (238 km)	0.084	12 km Max dv value

Table 7.5.2-1. Kentucky BART Exemption Modeling Results for Sources Exempted From BART			
Source	**Class I Area**	**Impact (Change in DV)**	**Modeling**
Calgon Carbon Corporation	Dolly Sods (284 km)	0.133	12 km Max dv value
	Great Smokey Mt. (290 km)	0.191	12 km Max dv value
	James River Face (282 km)	0.098	12 km Max dv value
	Linville Gorge (273 km)	0.103	12 km Max dv value
	Otter Creek (259 km)	0.157	12 km Max dv value
Westlake Vinyls Inc.	Mammoth Cave (183 km)	0.150	12 km Max dv value
	Mingo (156 km)	0.167	12 km Max dv value
	Sipsey1 (309 km)	0.084	12 km Max dv value
Century Aluminum*	Mammoth Cave (100 km)*	0.446	4km 8th Highest dv value
Alcan Primary Products Corporation	Mammoth Cave (118 km)	0.467	4km 8th Highest dv value
	Mingo (244 km)	0.184	4km 8th Highest dv value
NewPage**Corporation Wickliffe PaperCo.	Mammoth Cave (250 km)**	0.102	4km 8th Highest dv value
	Mingo (91 km)	0.291	4km 8th Highest dv value
	Sipsey (319 km)	0.060	4km 8th Highest dv value
Western Kentucky Energy Coleman Station	Mammoth Cave (91 km)	0.368	4km 8th Highest dv value
Western Kentucky Energy Reid/Henderson Station***	Mammoth Cave (118 km)	0.464***	***4km 8th Highest dv value
	Mingo (244 km)	0.072	4km 8th Highest dv value
Western Kentucky Energy Green Station	Mammoth Cave (118 km)	0.217	4km 8th Highest dv value
	Mingo (244 km)	0.039	4km 8th Highest dv value
Marathon Petroleum Company	Dolly Sods (287 km)	0.055	12 km Max dv value
	Great Smokey Mt. (293 km)	0.056	12 km Max dv value
	James River Face (287 km)	0.079	12 km Max dv value
	Linville Gorge (276 km)	0.041	12 km Max dv value
	Otter Creek (261 km)	0.086	12 km Max dv value
E. ON U.S. Brown Station	Mammoth Cave (130) km)	0.410	4km 8th Highest dv value
	Great Smokey Mt. (250 km)	0.210	4km 8th Highest dv value
	Joyce Kilmer-Slickrock (265 km)	0.153	4km 8th Highest dv value
E. ON U.S. Cane Run Station	Mammoth Cave (100) km)	0.378	4km 8th Highest dv value
E. ON U.S. Ghent Station	Mammoth Cave (190) km)	0.292	4km 8th Highest dv value

*Century Aluminum and **NewPage modeled below 0.5 dv with and without the new improve equation. ***Western Kentucky Energy Reid/Henderson Station BART exemption modeling was based exclusively on the use of the new improve equation. A copy of a request to EPA Region 4 requesting approval of the use of the new improve equation and a letter from EPA granting its approval of the request for these three sources are available in Appendix L.9. The modeled values in the above table for Century Aluminum and NewPage are for the old improve equation. The values for Western Kentucky Energy Reid/Henderson are for the new improve equation.

In Table 7.5.2-2, five of the twenty-six Kentucky BART-eligible sources that were unable to demonstrate exemption from BART based on CALPUFF modeling conducted using the VISTAS BART Modeling Protocol are provided.**.** The five sources found subject to BART are EGUs that are subject to BART because of their inorganic condensible particulate emissions (SO3, H2SO4). These subject BART sources were required to complete BART determination modeling, which included a five factor analysis, to determine appropriate BART controls for PM.

Table 7.5.2-2. Kentucky BART Exemption Modeling Results for BART-Subject Sources			
Source	**Class I Areas**	**Impact (Change in DV)**	**Modeling**
East Kentucky Power (EKPC) Cooperative Spurlock Station	Mammoth Cave (251 km)	1.834	4km 8th Highest dv value
East Kentucky Power (EKPC) Cooperative Cooper Station	Mammoth Cave (130 km)	7.376	4km 8th Highest dv value
	Great Smoky Mountains National Park (162 km)	6.763	4km 8th Highest dv value
	Joyce Kilmer-Slickrock Wilderness (178 km)	4.974	4km 8th Highest dv value
	Cohutta Wilderness Area (221 km)	3.363	4km 8th Highest dv value
	Shinning Rock (233 km)	2.022	4km 8th Highest dv value
	Linville Gorge Wilderness Area (267 km)	1.885	4km 8th Highest dv value
TVA Paradise Fossil Steam Plant	Mammoth Cave (63 km)	3.93	4km 8th Highest dv value
	Mingo (283 km)	0.865	4km 8th Highest dv value
American Electric Power (AEP) Big Sandy Plant	Dolly Sods (291 km)	1.027	4km 8th Highest dv value
	James River Face (279 km)	1.052	4km 8th Highest dv value
	Linville Gorge (256 km)	0.835	4km 8th Highest dv value
	Otter Creek (266 km)	1.285	4km 8th Highest dv value
E. ON U.S. Mill Creek Station	Mammoth Cave (90 km)	2.265	4km 8th Highest dv value

Fourteen of Kentucky's twenty-six BART-eligible sources are EGUs that are subject to CAIR.

The USEPA has determined that, as a whole, the CAIR cap-and-trade program improves visibility more than implementing BART for individual sources in states affected by CAIR. A State that opts to participate in the CAIR program under 40 CFR 96.201-.224 (Subpart AAA through EEE) need not require affected BART-eligible EGUs to install, operate, and maintain BART for SO2 or NOx emissions. Given that most BART-eligible units have existing or are installing scrubbers and NOx controls, and since Kentucky is participating in CAIR and accepts the USEPA's overall finding that CAIR "substitutes" for BART for NOx and SO2, Kentucky's EGUs were allowed to submit BART exemption modeling demonstrations for PM emissions only. Nine of the fourteen Kentucky EGUs demonstrated that they do not contribute to visibility impairment in any Class I area.

In total twenty-one of Kentucky's twenty-six BART-eligible sources were able to demonstrate that they did not cause or contribute to visibility impairment in any Class I area within 300 km of the source.

7.5.3 Determination of BART Requirements for Subject-to-BART Sources

Table 7.5.3-1 presents BART determination modeling results for the five Kentucky EGU sources that were unable to demonstrate a contribution of less than 0.5 dv at all Class I areas within 300 km from their source location. These five sources are considered to be "subject to BART" and were required to submit BART determination modeling containing their evaluation of potential BART control options and proposed BART determinations. Each of these sources has agreed to install emission controls to address inorganic condensible particulate emissions (SO3/H2SO4), which is causing the sources to be subject to BART. The BART determination resulting controls are provided in the Table 7.5.3-1 that follows and they were taken to public hearing concurrent with the public hearing on Kentucky's Regional Haze SIP. Table 7.5.3-2 that follows, in addition to the emission controls, provides the source's BART emission limits and timeframes for compliance. Applicable BART controls and emission limits will be incorporated into the sources' Title V permit as appropriate or upon renewal. In addition, since TVA had previously indicated to the KYDAQ its plans to install hydrated lime injection controls on TVA Paradise Units 1-3 to mitigate opacity due to SO3 emissions and that additional controls are not cost-effective at this time, the KYDAQ has determined BART to be no control for TVA Paradise Units 1-3. However, as related by TVA, the hydrated lime injection controls for TVA Paradise Units 1-3 will be in place well before the BART controls are required; will achieve the reduction in visibility impacts listed in the Draft Implementation Plan (Kentucky Regional Haze SIP); and will be included in TVA Paradise's Title V permit. Specifically, regarding the installation of hydrated lime injection controls for TVA Paradise Units 1-3, TVA has communicated to KYDAQ its proposed plan that provides for permitting activities to proceed in July 2008; for construction to begin in mid-2009 on Unit 3 with construction for Unit 1 and 2 to follow; and for controls to be operating on all three TVA Paradise units possibly by the fall of 2010. Also, as indicated in the E.ON U.S. Mill Creek BART determination submittal, the average cost for installing sorbent controls on all four Mill Creek units is about the same (an estimated 5.1 million $/dv). However, sorbent injection at all four units would mean an additional total capital investment of $8.8 million as compared to controls only on the larger Units 3 and 4. Therefore, E.ON U.S. concluded that BART should be the installation of sorbent injection controls on the larger Mill Creek Units 3 and 4 since they can achieve an estimated 70 percent of the total dv improvement achieved by controlling all four units. Given the extra cost for the lesser additional dv improvement for Units 1 and 2, the Cabinet agreed that BART for Mill Creek is the installation of sorbent injection controls on the larger Units 3 and 4. For further details about the BART determination modeling for the five BART-Subject sources, please refer to Appendix L.

Table 7.5.3-1 Kentucky BART Determination Modeling Results for BART-Subject Sources					
Source	**Class I Areas**	**BART Controls to Be Installed***	**98th Percentile Impact Before BART Controls (Change in dv)**	**98th Percentile Impact with BART Controls (Change in dv)**	**BART Determination Control Visibility Improvement From 98th Percentile value (Change in dv)**
East Kentucky Power Cooperative (EKPC) Spurlock Station	Mammoth Cave (251 km)	EKPC per a consent decree and for BART will install a wet FGD and wet ESP at EKPC Spurlock Units 1 and 2 that will address condensible particulate emissions and other visibility impairing pollutants.	1.834	0.213	1.621
East Kentucky Power Cooperative (EKPC) Cooper Station	Mammoth Cave (130) km	EKPC per a consent decree and for BART will install a wet FGD and wet ESP at EKPC Cooper Units 1 and 2 that will address condensible particulate emissions and other visibility impairing pollutants.	7.376	0.252	7.124
	Great Smoky Mountains National Park (162 km)		6.763	0.219	6.544
	Joyce Kilmer-Slickrock Wilderness (178 km)		4.974	0.122	4.852
	Cohutta Wilderness Area (221 km)		3.363	0.087	3.276
	Shinning Rock (233 km)		2.022	0.049	1.973
	Linville Gorge Wilderness Area (267 km)		1.885	0.046	1.839
TVA Paradise Fossil Steam Plant*	Mammoth Cave (63 km)	*Although not for BART, TVA previously indicated to KYDAQ its plans to install hydrated lime injection controls on TVA Paradise Units 1-3 to mitigate opacity due to SO3 emissions.	U1- 1.285 U2- 1.285 U3- 1.842 4.412 3.930	0.606 0.606 0.836 2.048 2.048	0.679 0.679 1.006 2.364 1.882
	Mingo (283 km)		U1- 0.251 U2- 0.251 U3- 0.381 0.883 0.865	0.116 0.116 0.166 0.398 0.398	0.135 0.135 0.215 0.485 0.467

Table 7.5.3-1 Kentucky BART Determination Modeling Results for BART-Subject Sources					
Source	**Class I Areas**	**BART Controls to Be Installed***	**98th Percentile Impact Before BART Controls (Change in dv)**	**98th Percentile Impact with BART Controls (Change in dv)**	**BART Determination Control Visibility Improvement From 98th Percentile value (Change in dv)**
American Electric Power Big Sandy Plant (AEP)	Dolly Sods (291 km)	Per a consent decree and BART, AEP will install ammonia injection on Unit 1 and a FGD scrubber on Unit 2 to address condensible particulate emissions and other visibility impairing pollutants.	1.027	0.496	0.531
	James River Face (279 km)		1.052	0.457	0.595
	Linville Gorge (256 km)		0.835	0.364	0.471
	Otter Creek (266 km)		1.285	0.558	0.697
E.ON U.S Mill** Creek Station	Mammoth Cave (90 km)	**E.ON U.S. for BART will install sorbent injection controls on the larger Units 3-4 to mitigate condensable particulate emissions.	2.265	1.440	0.825

*Since TVA had previously indicated to the KYDAQ its plans to install hydrated lime injection controls on TVA Paradise Units 1-3 to mitigate opacity due to SO3 emissions and that additional controls are not cost-effective at this time, the KYDAQ has determined BART to be no control for TVA Paradise Units 1-3. **Given the extra cost for the lesser additional dv improvement for Units 1 and 2, the Cabinet agreed that BART for Mill Creek is the installation of sorbent injection controls on the larger Units 3 and 4.

Table 7.5.3-2 Kentucky BART Controls, Emission Limits, and Compliance Timeframes for BART-Subject Sources				
Kentucky BART Subject Source	**BART Controls To Be Installed**	**BART Emission Limits**	**Inclusion in Title V Permit**	**Timeframe for Compliance with BART Emission Limits\Controls**
East Kentucky Power Cooperative (EKPC) Spurlock Units 1 and 2 and Cooper Units 1 and 2	Install wet FGD and wet ESP on Spurlock Units 1 and 2 and Cooper Units 1 and 2.	A 07/02/07 EKPC consent decree provides a filterable PM emission rate of 0.030 lb/MMBTU, which was utilized to demonstrate modeled visibility improvement.	Emission limits and controls will be included in the source's Title V Permit as appropriate or on renewal.	Expeditiously as practicable, but no later than 5 years after EPA approves Kentucky's Regional Haze SIP.
AEP Big Sandy Unit 1 Unit 2	Install ammonia injection controls on Unit 1 and a FGD on Unit 2.	Inorganic Condensible Particulate Limits (modeled as sulfates): 101.0 lb/hr (H_2SO_4) 127.0 lb/hr (H_2SO_4)	Emission limits and controls will be included in the source's Title V Permit as appropriate or on renewal.	Expeditiously as practicable, but no later than 5 years after EPA approves Kentucky's Regional Haze SIP. KYDAQ will work with AEP to install the FGD scrubber on AEP Big Sandy Unit 2 as expeditiously as practicable.
TVA Paradise* Unit 1 Unit 2 Unit 3	*Although not for BART, TVA previously indicated to KYDAQ its plans to install hydrated lime injection controls on TVA Paradise Units 1-3 to mitigate opacity due to SO_3 emissions.	*NA	*Although not for BART, TVA has indicated that its planned SO_3 controls for Paradise Units 1-3 will be included in its Title V Permit as appropriate or on renewal.	*Although not for BART, TVA in its BART Determination has indicated the SO_3 controls will be in place on Paradise Units 1-3 well before BART controls are required. Specifically, TVA has related to

Table 7.5.3-2 Kentucky BART Controls, Emission Limits, and Compliance Timeframes for BART-Subject Sources				
Kentucky BART Subject Source	**BART Controls To Be Installed**	**BART Emission Limits**	**Inclusion in Title V Permit**	**Timeframe for Compliance with BART Emission Limits\Controls**
				KYDAQ its proposed plan to have hydrated lime injection controls operating on all three TVA Paradise units possibly by the fall of 2010.
E.ON U.S.** Mill Creek Unit 3 Unit 4	**Install sorbent injection controls on larger Units 3 and 4 to control SO3 emissions and continue to utilize existing ESPs to control PM emissions for Units 1 through 4.	Inorganic Condensible Particulate Limits (modeled as sulfates): 64.3 lb/hr (H2SO4) 76.5 lb/hr (H2SO4)	**Emission limits and controls will be included in the source's Title V Permit as appropriate or on renewal.	**Expeditiously as practicable, but no later than 5 years after EPA approves Kentucky's Regional Haze SIP.

*Since TVA had previously indicated to the KYDAQ its plans to install hydrated lime injection controls on TVA Paradise Units 1-3 to mitigate opacity due to SO3 emissions and that additional controls are not cost-effective at this time, the KYDAQ has determined BART to be no control for TVA Paradise Units 1-3. **Given the extra cost for the lesser additional dv improvement for Units 1 and 2, the Cabinet agreed that BART for Mill Creek is the installation of sorbent injection controls on the larger Units 3 and 4.

7.6 Relative Contributions to Visibility Impairment: Geographic Areas of Influence for Kentucky's Class I Area

Once it was determined that SO2 emission reductions from EGU and non-EGU point sources in the VISTAS states would be the most effective sources to control to improve visibility at Kentucky's Class I area, the next step was to identify the specific geographic areas that most likely influence visibility in each Class I area, and then to identify the major SO2 point sources located in those geographic areas. An SO2 Area of Influence was defined for each Class I area to represent the geographic area containing sources that would likely have the greatest impact on visibility at that Class I area. All SO2 point sources within these Areas of Influence were identified and ranked by their 2018 emissions. The following sections contain a broad overview of the steps in the Area of Influence analyses. See Appendix H for a more detailed discussion of these analyses and plots for Kentucky's Class I area. The plots that follow are only for Kentucky's Class I area since KYDAQ's Q/d times RTMax area of influence analysis identified no Kentucky sources that contributed one percent or more to visibility impairment for any other Class I area examined by VISTAS.

7.6.1 Back Trajectory Analyses

The first step was to generate meteorological back trajectories for IMPROVE monitoring sites in Kentucky and neighboring Class I areas for the 2000-2004 20 percent worst days baseline period. Back trajectory analyses use interpolated measured or modeled meteorological fields to estimate the most likely central path of air masses that arrive at a receptor at a given time. The method essentially follows a parcel of air backward in hourly steps for a specified length of time. Figure 7.6.1-1 is an example back trajectory analysis for Mammoth Cave National Park for the 20 percent worst days in 2002.

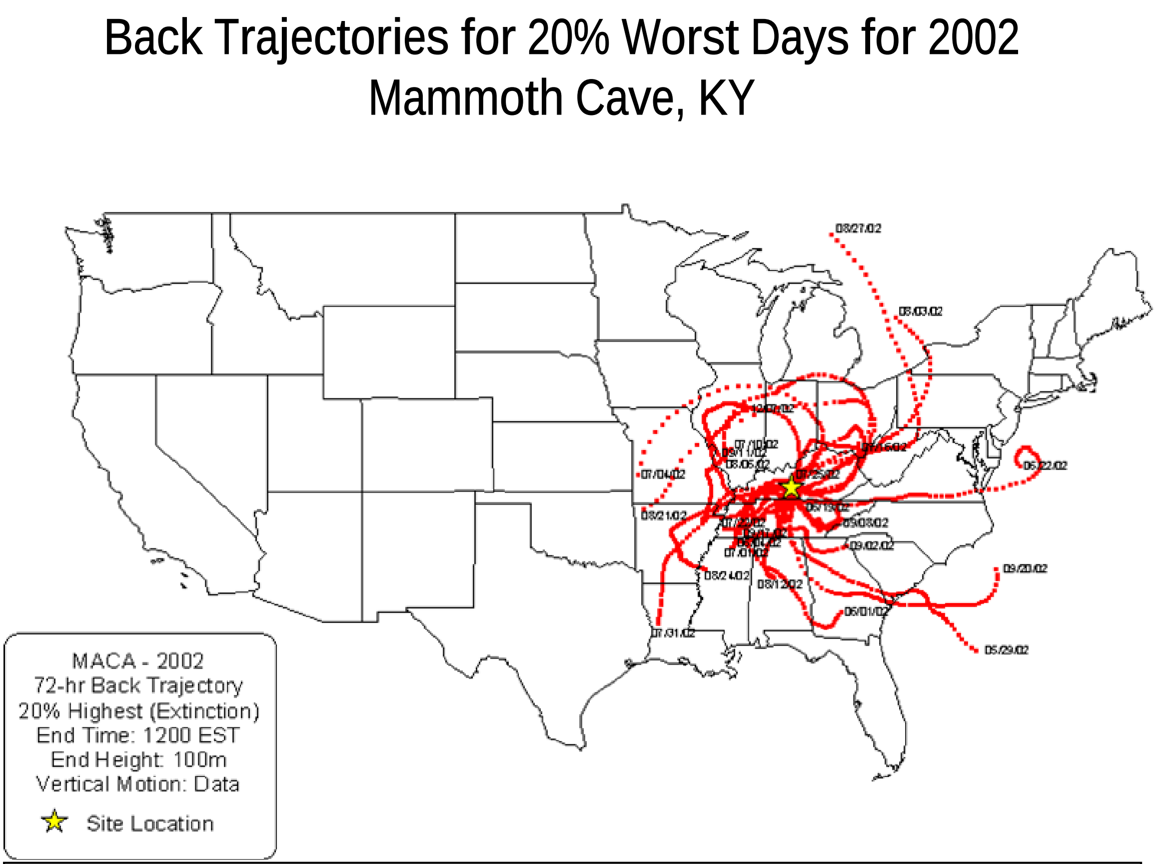


Figure 7.6.1-1. Example back trajectories for 20 percent worst visibility days in 2002 for Mammoth Cave National Park.

Trajectories were started at 100 meters and 500 meters above the surface and run backward from the site for 72-hours. These individual back trajectories for 20 percent worst days in 2002 were also useful in evaluating model performance for individual days at the Class I areas.

7.6.2 Residence Time Plots

The next step was to plot residence time for each Class I area using five years of back trajectories for the 20 percent worst visibility days in 2000-2004. Residence time is the frequency that winds pass over a specific geographic area on the path to a Class I area. Separate residence time plots were generated using trajectories with 100m and 500m start heights. As illustrated in Figure 7.6.2-1, winds influencing Mammoth Cave on the 20 percent worst days come from all directions and there is no single predominant wind direction influencing the 20 percent worst visibility days.

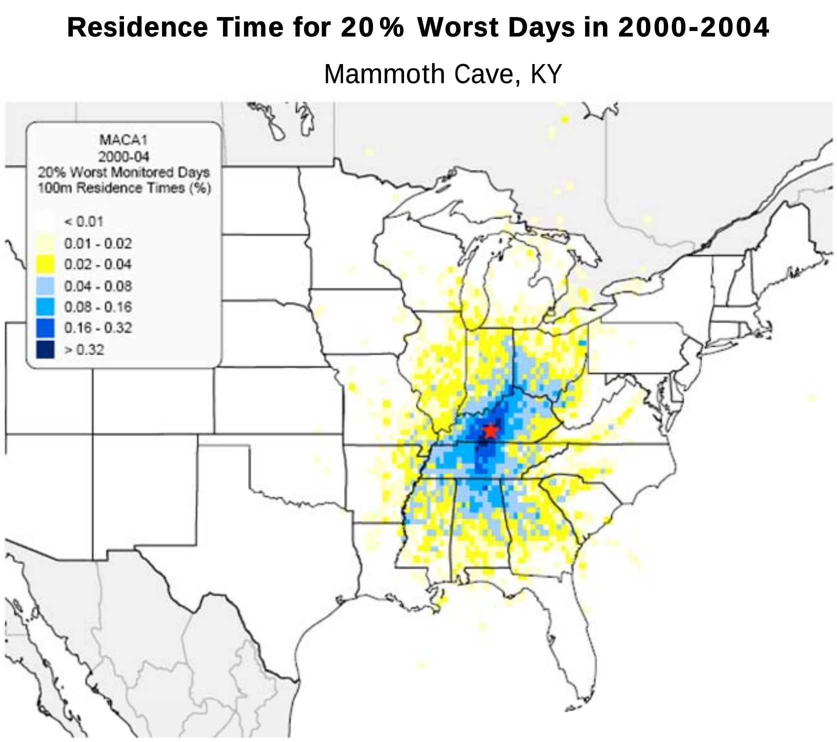


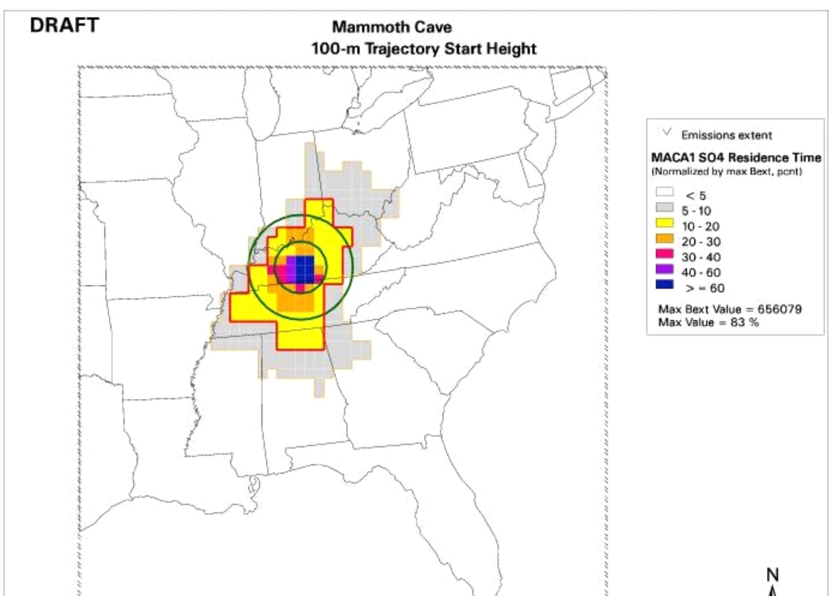
Figure 7.6.2-1 Example residence time plot for 20 percent worst visibility days in 2000-2004 for Mammoth Cave National Park. Based on trajectories with 100m start height.

7.6.3 SO2 Areas of Influence

As discussed earlier, the KYDAQ has determined that reductions in SO2 emissions would have the greatest visibility impact. Therefore, sulfate extinction-weighted residence time plots were developed to define the geographic area with highest probability of influencing the receptor on the 20% worst days in the 2000-2004 baseline period that were dominated by sulfate. Each back trajectory was weighted by sulfate extinction for that day. This allows the focus to be on the 20 percent worst days that are influenced by sulfate and places less importance on days influenced by organic carbon from fires. Sulfate-weighted back trajectories for the 20 percent worst days were combined for 5 years of data. The resulting sulfate extinction-weighted residence time plots were used to define the geographic Area of Influence for sources of SO2 emissions. In Figure 7.6.3-1 the area representing 10 percent or greater residence time is outlined in red and the area representing 5 percent or greater residence time is outlined in gray.

The VISTAS states discussed various options as to what percentage of sulfate extinction-weighted area of influence should be assessed. It was determined that for this planning period that the area of influence defined by 5% or greater sulfate extinction-weighted residence time provided a reasonable universe of sources that may cause visibility impairment at a Class I area. The VISTAS states recognized that this did not represent 100% of the sources contributing to visibility impairment at Class I areas, but rather a reasonable universe of sources to consider during the first planning period.

SO2 Area of Influence for Mammoth Cave, KY



Green circles indicate 100-km and 200-km radii from Class I area.
Red line perimeter indicate Area of Influence with Residence Time $\geq$ 10%
Orange line perimeter indicate Area of Influence with Residence Time $\geq$ 5%.

Figure 7.6.3-1 Example SO2 Area of Influence plot for sulfate extinction weighted residence time for 20 percent worst visibility days in 2000-2004 for Mammoth Cave National Park based on trajectories with 100m start height.

7.6.4 Emissions Sources within SO2 Areas of Influence

Residence time plots were then combined with geographically-gridded emission data based on the 2002 baseline and 2018 emissions inventories. Plots were generated for the Areas of Influence defined by trajectories with 100m and 500 m start heights. As a way of incorporating the effects of transport, deposition, and chemical transformation of point source emissions along the path of the trajectories, these data were weighted by 1/d, where d was calculated as the distance, in kilometers, between the center of the grid cell in which a source is located and the center of the grid cell in which the IMPROVE monitor is located. The distance-weighted point source SO2 emissions are then combined with the gridded extinction-weighted back-trajectory residence times at a spatial resolution of 36-km.

The final step was to combine the residence times and gridded emissions data in plots and data sets. The distance weighted (1/d) gridded point source SO2 emissions were multiplied by the total extinction-weighted back-trajectory residence times on a grid cell by grid cell basis. These results were then normalized by the domain-wide total and displayed as a percentage. The analysis was done using both the 2002 and 2018 emissions inventories.

Figure 7.6.4-1 illustrates the 2002 and 2018 distance weighted gridded emissions multiplied by sulfate extinction weighted residence time for Mammoth Cave National Park. These maps help visualize where the emissions reductions will be occurring between 2002 and 2018. The change in SO2 emissions between 2002 and 2018 can be seen by comparing emissions source strengths in the two plots. Note the emissions from each source are normalized by the total emissions in the domain. Sources that reduce SO2 emissions by 2018 will show a lower contribution to emissions in the domain. On the 2018, map the grid cells with these sources will show a lighter color gradient than on the 2002 map**.** For example, SO2 reductions from EGUs from west to east in Kentucky for CAIR can be seen by comparing the 2002 and 2018 maps. Because the total emissions in the domain are smaller in 2018, a source that does not change emissions between 2002 and 2018 may actually appear to increase in importance in 2018 compared to 2002.

Although the sulfate extinction-weighted residence times were developed using the 2002 emissions, the 2018 emissions weighted by residence time plots still provides useful information. The KYDAQ does not believe that the area of influence would have changed significantly if sulfate extinction-weighted residence times were developed using the 2018 emissions. However, if the area of influence would have been smaller using 2018 emissions due to reductions expected in the EGU source sector, then the area developed to identify potential sources would be considered conservative.

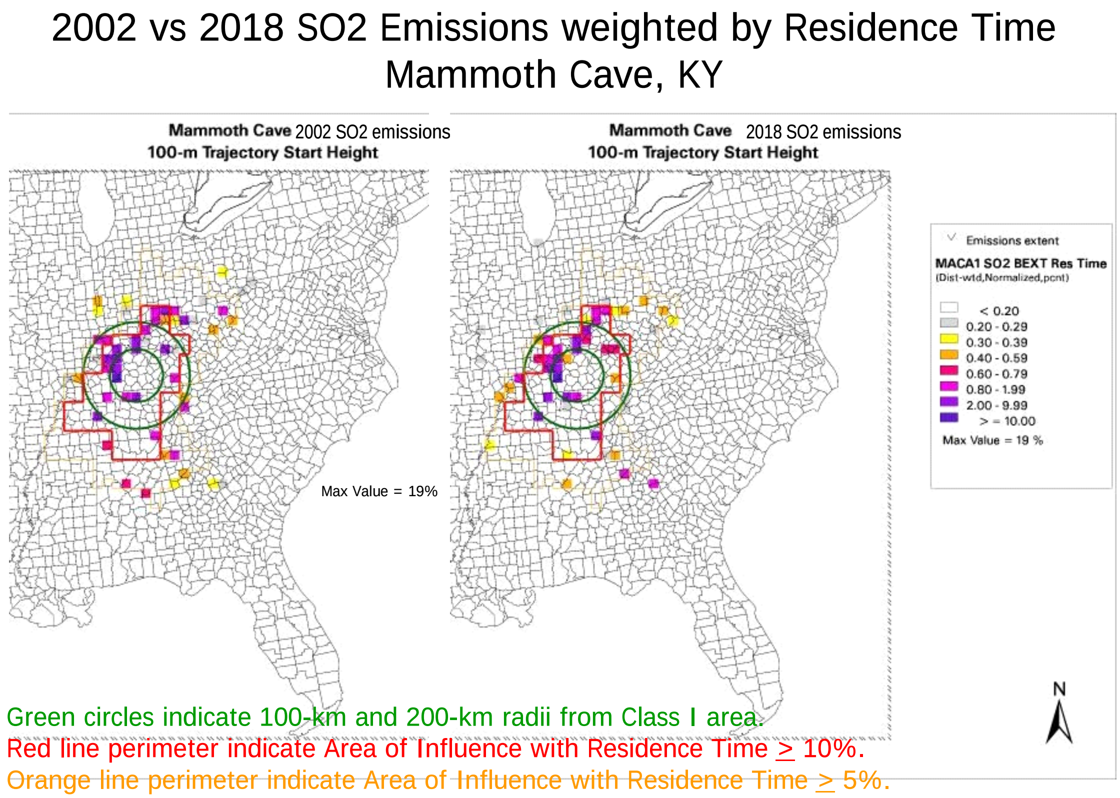
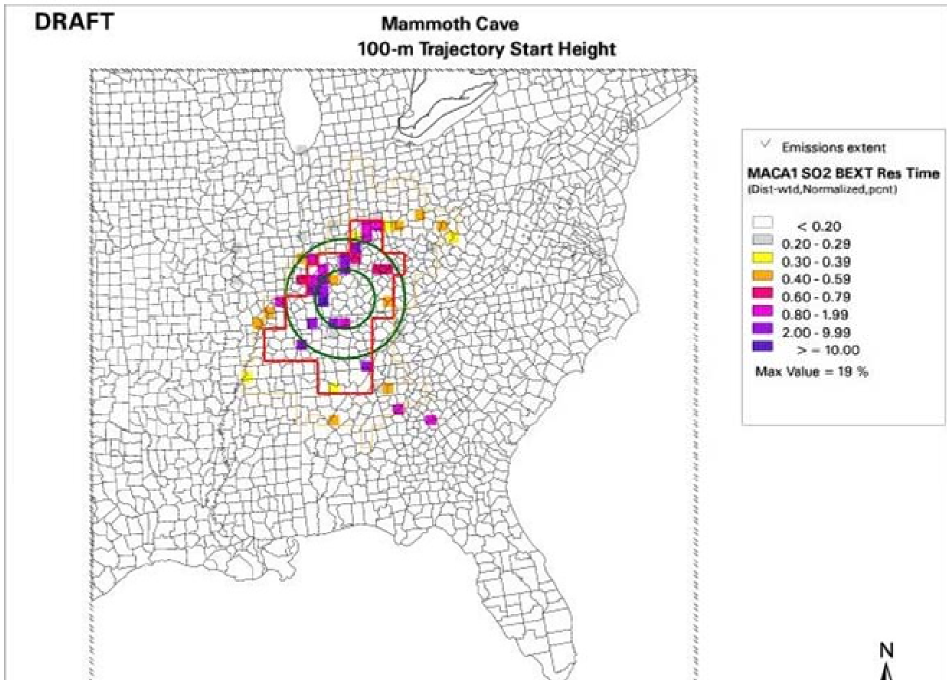


Figure 7.6.4-1. Mammoth Cave National Park 2002 (left) and 2018 (right) SO2 distance weighted emissions times SO4 extinction-weighted residence time plots.

Figure 7.6.4-2 illustrates similar plots for 2018 for Mammoth Cave National Park. These plots illustrate the relative importance of Kentucky sources of SO2 compared to sources in neighboring states. Additional analyses, including 2002 and 2018 distance weighted emissions times residence-time plots for the Class I area in Kentucky and neighboring states are contained in Appendix H. These analyses are serving as the basis for consultation among the VISTAS states.

2018 SO2 Emissions weighted by Residence Time
Mammoth Cave, KY



Green circles indicate 100-km and 200-km radii from Class I area.
Red line perimeter indicate Area of Influence with Residence Time $\geq$ 10%.
Orange line perimeter indicate Area of Influence with Residence Time $\geq$ 5%.

Figure 7.6.4-2. Mammoth Cave 2018 SO2 distance weighted emissions times SO4 extinction-weighted residence time plot.

Finally, Table 7.6.4-1 shows, in tabular form, the relative contributions of point source SO2 emissions from nearby states to Kentucky's Class I area. These percentages were estimated by multiplying the maximum residence time to the emissions over distance.

Table 7.6.4-1 2018 Point Source SO2 Contribution to Kentucky's Class I Area by State

State	Kentucky Class I Area Mammoth Cave
Alabama	4.33%
Arkansas	
Delaware	
Florida	
Georgia	1.79%
Illinois	0.53%
Indiana	21.22%
Iowa	
Kansas	

State	Kentucky Class I Area Mammoth Cave
Kentucky	53.60
Louisiana	
Maryland	
Michigan	
Minnesota	
Mississippi	
Missouri	0.53
Nebraska	
New Jersey	
New York	
North Carolina	
Ohio	3.95%
Pennsylvania	
South Carolina	
Tennessee	13.46%
Virginia	
West Virginia	0.54
Wisconsin	
Total	100.00%

7.6.5 Specific Source Types in the Areas of Influence for Kentucky's Class I Area

The next step in the analysis was to review the emissions inventories to determine the source categories, as well as specific sources, found to have the greatest impact on visibility in Kentucky's Class I area. Lists of SO2 point sources within the Areas of Influence for each Class I areas were developed using the VISTAS 2002 base year and 2018 future year emissions. For this purpose, the Area of Influence was defined as the counties with maximum sulfate extinction weighted residence time greater than five. For SO2 sources within each Area of Influence, the following attributes were defined for each individual unit:

- State, county, and source (plant), and industry identification codes
- SO2 emissions for 2002 and 2018
- 2018 control efficiency
- Distance to Class I areas (defined by distance to the monitor at the Class I area)
- Emissions divided by distance (Q/d), a metric that accounts for the dispersion of emissions over distance
- Maximum sulfate extinction weighted residence time (RTmax)

Our review was conducted in a top down fashion starting with an analysis of the major source categories in each SO2 Area of Influence to determine which major categories had the highest residual contribution to the area in 2018. It was also important to identify reductions that are projected to occur between 2002 and 2018 within each category or at specific units. This allowed VISTAS States to determine if certain source categories or units that had yet to be controlled under the future year base case had the potential for reduction. Once the highest source types were identified, subcategories within those source types were reviewed. The contributions from major source categories to the 2018 inventory for the SO2 Areas of Influence for the Kentucky Class I area~~s~~ are listed in Table 7.6.5-1. In these tables, the source categories are broken out by the USEPA’s Tier 1 report categories and are defined below:

• Fuel Comb Elec Utility	Emissions from all fuel combustions at utility boilers
• Fuel Comb Industrial	Emissions from all fuel combustions at industrial boilers
• Fuel Comb Other	Emissions from all fuel combustions from commercial/institutional and residential sources (i.e., fireplaces, natural gas stoves, oil heaters, etc.)
• Chemical & Allied Product Mfg	Emissions from chemical manufacturing processes
• Metal Processing	Emissions from metal processing operations
• Petroleum & Related Industries	Emissions from petroleum refineries & related industries
• Other Industrial Processes	All other industrial processing not previously mentioned
• Solvent Utilization	Emissions from solvent utilization such as degreasing operations, surface coating operations, etc.
• Storage & Transport	Emissions from storage and transport of petroleum, organic and inorganic products
• Waste Disposal & Recycling	Emissions from open burning, incineration, landfills, publicly owned treatment works, treatment storage and/or disposal facilities, wastewater treatment facilities
• Highway Vehicles	Emissions from on-road mobile sources
• Off-highway	Emissions from off-road mobile sources
• Miscellaneous (Ag, Fires)	Emissions from agricultural operations, wildland fires, and other emissions sources not previously mentioned

Table 7.6.5-1. 2018 SO2 Emissions Contributions from Major Source Categories in the Area of Influence for Mammoth Cave National Park, Kentucky.

Tier	VOC	NOX	CO	SO2	PM-10	PM-2.5	NH3
Fuel Comb. Elec. Util.	1%	25%	1%	66%	8%	18%	1%
Fuel Comb. Industrial	1%	16%	2%	19%	3%	6%	0%
Fuel Comb. Other	4%	7%	3%	5%	3%	8%	0%
Chemical & Allied Product Mfg	2%	1%	1%	1%	1%	1%	1%
Metals Processing	1%	1%	5%	3%	3%	7%	0%
Petroleum & Related Industries	1%	0%	0%	1%	0%	0%	0%
Other Industrial Processes	7%	5%	1%	3%	8%	10%	1%
Solvent Utilization	45%	0%	0%	0%	0%	0%	0%
Storage & Transport	6%	0%	0%	0%	1%	1%	0%
Waste Disposal & Recycling	3%	1%	2%	0%	3%	7%	0%
Highway Vehicles	17%	20%	48%	0%	1%	2%	9%
Off-highway	12%	24%	36%	1%	2%	4%	0%
Miscellaneous	1%	0%	3%	0%	69%	35%	87%
VISTAS Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

These tables indicate that for Kentucky's Class I area, EGUs and industrial boilers are the two major sources categories contributing to 2018 SO2 emissions in the Areas of Influence, even after implementation of CAIR. Together these two source categories contribute 85 percent of the 2018 SO2 emissions for the Areas of Influence for Kentucky's Class I area. Other fuel combustion and other industrial processes comprise another 8 percent of the 2018 SO2 emissions.

These tables can also be used to evaluate the major source categories contributing to emissions of NOx, NH3, and PM emissions in 2018. For instance, highway vehicles and off road vehicles are major sources of NOx emissions, in addition to electric utilities and industrial boilers. The source category "miscellaneous" (which includes agricultural sources and fires) is the major contributor to NH3 and primary PM. However, based upon the 2000 - 2004 reconstructed extinction for the 20% worst visibility days (Appendix B), these pollutants are not significant contributors to visibility impairment on most days in the baseline period. Additionally, the emissions sensitivities discussed in Section 7.4 indicated very small benefits of controlling NOx, NH3, and primary PM emissions at Kentucky's Class I area, but if these emissions were of concern, different source categories would need to be addressed.

The contributions to SO2 emissions in 2018 from the three highest source categories, electric utilities, industrial boilers, and other fuel combustion have been further broken out into subcategories. Table 7.6.5-2 indicates subcategories for the Areas of Influence for Kentucky's Class I area. Within electric utilities, all the SO2 emissions are attributable to coal fired power plants. Within industrial boilers, most emissions are attributable to coal fired boilers with lesser contributions from oil and gas boilers. Commercial and institutional coal and oil boilers have smaller contributions.

Table 7.6.5-2. 2018 SO2 Emissions Contributions from Major Source Subcategories in the Area of Influence for Mammoth Cave National Park, Kentucky.

Tier	MACA
Fuel Comb. Elec. Util.-Coal	66%
Fuel Comb. Elec. Util.-Oil	0%
Fuel Comb. Elec. Util.-Gas	0%
Fuel Comb. Elec. Util.-Other	0%
Fuel Comb. Elec. Util.-Internal Combustion	0%
Fuel Comb. Industrial-Coal	14%
Fuel Comb. Industrial-Oil	3%
Fuel Comb. Industrial-Gas	2%
Fuel Comb. Industrial-Other	1%
Fuel Comb. Industrial-Internal Combustion	0%
Fuel Comb. Other-Commercial/Institutional Coal	2%
Fuel Comb. Other-Commercial/Institutional Oil	2%
Fuel Comb. Other-Commercial/Institutional Gas	0%
Fuel Comb. Other-Misc. Fuel Comb. (Except Residential)	0%
Fuel Comb. Other-Residential Wood	0%
Fuel Comb. Other-Residential Other	1%

From these analyses, the KYDAQ considered what additional control measures for electric utilities and industrial boilers are reasonable. The lists of individual sources are also being used to determine if individual sources in other sources categories are major contributors to SO2 emissions in the Areas of Influence.

7.7 Evaluating the Four Statutory Factors for Specific SO2 Emissions Sources in Each Area of Influence

The next step was to identify emission reductions that have already occurred within each source category and at specific units. Unit level tables of emission comparisons from 2002 to 2018 were developed, allowing VISTAS States to review existing emission reductions. These tables assigned future year control technology from IPM forecasting and State modification for EGU and from control efficiency tables for non-EGU point sources.

Once emission control profiles for specific units were defined, the next step is to determine what, if any, additional control measures would feasibly be available, and to assign costs to those control measures. For EGUs, the 2018 IPM file used by VISTAS was obtained and matched to the 2018 base case inventory of EGU sources. This step was conducted to ensure that incremental controls assigned to these source types did not duplicate existing base case assumptions.

VISTAS used the USEPA's AirControlNET database, modified for the VISTAS emission inventories, for the non-EGUs. The core of AirControlNET is a relational database system in which control technologies are linked to sources within the USEPA emissions inventories. The system contains a database of control measure applicability, efficiency, and cost information for reducing emissions. The control measure data file in AirControlNET includes not only the technology's control efficiency, and calculated emission reductions for that source, but also estimates the costs (annual and capital) for application of the control measure.

Using the modified inventories identified above, VISTAS ran every available SO2 control strategy in AirControlNET against the EGU and non-EGU point source inventories to develop a master list of incremental control strategies for each unit in the VISTAS 36 km domain.

For the sources within the Area of Influence for Kentucky's Class I area, the master list of incremental control measures was sorted to determine the costs of incremental control measures. These data were combined in a master spreadsheet with the distance from the emission release point to the Class I area IMPROVE monitor (in km), the 2018 residual emissions and distance (Q/d) or squared distance (Q/d^2), and the normalized 2018 SO2 point source emissions times distance-weighted residence time (RTMax) values for the county in which the emission release point was located. Kentucky evaluated these control measures and costs as part of their review of the statutory factors for reasonable further progress.

The regional haze rule requires that states consider the following factors and demonstrate how these factors were taken into consideration in selecting the reasonable progress goal:

- the costs of compliance
- the time necessary for compliance
- the energy and non-air quality environmental impacts of compliance, and
- the remaining useful life of any potentially affected sources.

Cost of Compliance:
As defined in Section 7.6.5, coal-fired electric utilities and coal-fired industrial boilers were the largest source categories contributing to SO2 in 2018 in the Areas of Influence defined for Kentucky's Class I area. Industrial boilers using oil and commercial and institutional boilers using coal or oil had small contributions to SO2 in 2018.

Sulfur dioxide emissions from utility, industrial, commercial, or institutional boilers can be controlled either by switching the fuel source to a lower sulfur fuel content or by installing post-combustion controls. Costs vary by fuel source and boiler type and require source specific analyses for accuracy.

Bituminous coal is commonly burned in boilers in the eastern US. Switching to another bituminous coal with lower sulfur content or blending bituminous coals can reduce SO2 emissions with least impact to boiler performance. While sub-bituminous coal has a lower sulfur content than bituminous coal, it also has a lower heat rate and so more coal has to be burned to generate the same energy output. For boilers that are designed for bituminous coal, only a small fraction of the fuel can be switched to low sulfur sub-bituminous coal without affecting boiler operations. Costs of boiler modifications to accommodate low sulfur sub-bituminous coal may make switching to sub-bituminous coal impractical. Contract initiation and termination costs, differential fuel prices and heat rates, transportation costs, and modification to boiler operations, fuel handling and waste handling systems will have to be considered specific to each source.

Flue-gas desulfurization is the common post-combustion control for coal-fired boilers. Flue gas is passed through an absorbent for sulfur dioxide (generally limestone or lime) in either a wet scrubber, dry scrubber, or spray dryer. A calcium sulfate by-product is produced that may be further processed to produce gypsum as a commercial byproduct. Costs of flue-gas desulfurization include initial construction costs and ongoing operational and maintenance costs for the absorber tower, sorbent handling, and waste product handling facilities. Costs per ton vary with boiler size, type, and facility siting considerations.

For oil-fired boilers, lower sulfur oil may be an option. Costs need to consider differential fuel prices and heat rate, boiler modifications, fuel handling costs, and maintenance costs. Conceptually, post-combustion controls can be used for oil boilers, but there is little precedence for such installations.

Time Necessary for Compliance:
For fuel switching, the time necessary to terminate existing fuel contracts and initiate new contracts needs to be considered. Generally two to three years may be required. Installation of post-combustion controls will require 3 or more years depending on market availability of labor and materials and utility system-wide priorities. Time necessary for compliance will need to be refined for specific sources.

Energy and Non-Air Environmental Impacts:
Switching to lower sulfur fuel or installing post-combustion controls may reduce boiler heat rate and energy output. Scrubbers and spray dryers will require additional safeguards for fuel handling and waste handling systems to avoid additional non-air environmental impacts such as

increased effluents in waste water discharges and storm water runoff. These factors will need to be considered specific to individual sources. Carbon dioxide is emitted as a by-product of flue gas desulfurization, therefore impacts of increased carbon emissions will need to be considered, particularly if carbon emissions are limited in the future under climate change mitigation strategies.

Remaining Useful Life:
The useful remaining life is specific to the unit for which controls are considered.

7.8 Which Control Measures Represent Reasonable Progress for Individual Sources?

The following summarizes the process for determining reasonable progress for Kentucky sources. For a detailed discussion of the reasonable progress assessments for all units with a contribution of greater than one percent to visibility impairment at the Class I area in Kentucky or in neighboring states, please see Appendix H.

<u>Step 1: Determine pollutants of concern.</u>

VISTAS evaluated the species contribution on the 20 percent worst visibility days in the baseline period and concluded that sulfate accounted for greater than 70 percent of the visibility impairing pollution. The VISTAS States concluded that controlling SO2 emissions was the appropriate step in addressing the reasonable progress assessment for 2018. The VISTAS findings were consistent with the findings of SAMI. As you recall, SAMI confirmed that sulfate particles account for the greatest portion of the haze affecting Class I areas in the Southern Appalachian region and that these sulfates were produced in large part from SO2 emissions from coal combustion.

<u>Step 2: Determine which source sectors should be evaluated for reasonable progress.</u>

Since the pollutant of primary concern was determined to be SO2, the emissions inventory was assessed to determine the source categories that contribute the most SO2 emissions. Since point source emissions in 2018 are projected to represent greater than 95 percent of the total SO2 emissions inventory, the VISTAS States concluded that the focus should be on electric generating unit (EGU) and non-EGU point sources of SO2 emissions.

<u>Step 3: Determine if the Clean Air Interstate Rule is sufficient for reasonable progress for subject EGUs.</u>

The KYDAQ evaluated the amount of SO2 reduction from the EGU sector resulting from the implementation of the CAIR. The EGUs in Kentucky are expected to reduce their 2002 SO2 emissions by an estimated 54 percent by 2018. Much of that reduction is the result of requirements that are predicted by the IPM to meet CAIR.

To further support EGUs subject to CAIR is sufficient for reasonable progress, a discussion in the CAIR rule highlighted below (See Appendix H for 70 FR 25197-25198) addresses the reasonable progress factors of cost and time necessary for compliance for these EGUs, and provide the necessary support for a State's four factor reasonable progress analysis that must accompany a State’s assertion that CAIR is sufficient for reasonable progress for subject EGU’s during the first planning period.

> *From past experience in examining multi-pollutant emissions trading programs for SO2 and NOX, EPA recognized that the air pollution control retrofits that result from a program to achieve highly cost-effective reductions are quite significant and can not be immediately installed. Such retrofits require a large pool of specialized labor resources, in particular, boilermakers, the availability of which will be a major limiting factor in the amount and timing of reductions.*
>
> *Also, EPA recognized that the regulated industry will need to secure large amounts of capital to meet the control requirements while managing an already large debt load, and is facing other large capital requirements to improve the transmission system. Furthermore, allowing pollution control retrofits to be installed over time enables the industry to take advantage of planned outages at power plants (unplanned outages can lead to lost revenue) and to enable project management to learn from early installations how to deal with some of the engineering challenges that will exist, especially for the smaller units that often present space limitations.*
>
> *Based on these and other considerations, EPA determined in the NPR that the earliest reasonable deadline for compliance with the final highly cost-effective control levels for reducing emissions was 2015 (taking into consideration the existing bank of title IV SO2 allowances). First, the Agency confirmed that the levels of SO2 and NOX emissions it believed were reasonable to set as annual emissions caps for 2015 lead to highly cost-effective controls for the CAIR region.*
>
> *Once EPA determined the 2015 emissions reductions levels, the Agency determined a proposed first (interim) phase control level that would commence January 1, 2010, the earliest the Agency believed initial pollution controls could be fully operational (in today's final action, the first NOX control phase commences in 2009 instead of in 2010, as explained in detail in section IV.C). The first phase would be the initial step on the slope of emissions reductions (the glide-path) leading to the final (second) control phase to commence in 2015. The EPA determined the first phase based on the feasibility of installing the necessary emission control retrofits, as described in section IV.C.*
>
> *Although EPA's primary cost-effectiveness determination is for the 2015 emissions reductions levels, the Agency also evaluated the cost effectiveness of the first phase control levels to ensure that they were also highly cost effective. Throughout this preamble section, EPA reports both the 2015 and 2010 (and 2009 for NOX) cost-effectiveness results, although the first phase levels were determined based on feasibility rather than cost effectiveness. The 2015 emissions reductions include the 2010 (and 2009 for NOX) emissions reductions as a subset of the more stringent requirements that EPA is imposing in the second phase.*

The KYDAQ intends to re-evaluate the IPM predictions of SO2 reductions for CAIR at the time of the next periodic report in 2012 to ensure that the reductions currently predicted by IPM for CAIR are in fact taking place where they were expected and needed. If KYDAQ’s assessment for the periodic report indicates that its emissions are likely not to meet 2018 projections then the KYDAQ may re-evaluate the four factors to re-assess the Long-Term Strategy. Based on the controls currently being installed for CAIR, required by BART, consent decrees, and predicted by IPM under CAIR, the KYDAQ has concluded that at this time these existing regulatory programs constitute reasonable control measures for Kentucky EGUs during this first assessment period (between baseline and 2018).

Step 4: Determine which emission units would be evaluated based on impact.

The KYDAQ calculated the fractional contribution from all emission units within the SO2 Area of Influence for a given Class I area and identified those emission units with a contribution of one percent or more to the visibility impairment at that Class I area. A full description of this process and a list of sources considered in the reasonable progress evaluation can be found in Appendix H.

Step 5: Evaluate the four factors.

Each emission unit identified in Step 4 above was considered for evaluation using the statutory and regulatory factors of 1) cost of compliance, 2) time necessary for compliance, 3) the energy and non-air quality environmental impacts of compliance, and 4) the remaining useful life of the emissions unit. If any control measure for an emission unit was found reasonable after assessing the four factors, modeling would be performed to determine if the controls would result in a visibility improvement at any Class I area.

For the limited purpose of evaluating the cost for the reasonable progress assessment in this first regional haze SIP, the KYDAQ believes it is not equitable to require Non-EGUs to bear a greater economic burden than EGUs for a given control strategy. The KYDAQ used EPA's CAIR EGU cost analysis to establish a cost/ton of SO2 removed threshold. During the current reasonable progress assessment, no units in Kentucky were identified for additional control since no measures were found to be below the cost threshold. Below is a summary of the analysis. The detailed analysis is included in Appendix H.

Results of four-factor analysis

The following is a brief summary of the Non-EGU four-factor analysis. Additional detail is included in Appendix H. The KYDAQ used the cost of compliance as a screening tool to determine the universe of sources to perform the full four-factor evaluation. Therefore, the summary is focused on the cost of control. The dollar per ton of SO2 removed threshold that the KYDAQ used to determine if the cost was reasonable was based on EPA's CAIR cost analysis for implementing CAIR (See EPA's CAIR cost analysis in 70 FR 25201-25208 12May2005 available in Appendix H). After a review of EPA's CAIR cost analysis, the KYDAQ determined that the CAIR SO2 control costs vary by year of analysis (2010 vs. 2015) and may range from $400 to $3,400 per ton of SO2 removed. Ultimately, EPA found a consistent marginal cost for both years at $2000 per ton, which KYDAQ believes establishes an appropriate threshold against which cost-effectiveness may be evaluated for reasonable progress. During the current reasonable progress assessment, no Non-EGU units in Kentucky were identified for additional control because no measures were found to be cost-effective.

For Non-EGUs, KYDAQ found that emissions from the following facility contributed one percent or more to visibility impairment in a Class I area, and therefore focused the reasonable progress assessments on specific units at this facility:

- Century Aluminum of Kentucky for impacts at Mammoth Cave.

The KYDAQ also looked at what sources in Kentucky may be impacting Class I areas located outside of the Kentucky, as well as what sources located outside of Kentucky may be impacting Kentucky's Class I area. KYDAQ, based on its Q/d times RTMax analysis identified eight EGUs, six from Indiana and two from Tennessee, with a one percent or more contribution for the Mammoth Cave area of influence. KYDAQ sent letters to Indiana and Tennessee indicating that no additional controls are requested at this time since Mammoth Cave is currently exceeding the uniform rate of progress and the EGUs are being addressed by CAIR (See copies of the letters in Appendix J). In addition, based on the KYDAQ Q/d times RTMax analysis, no Kentucky sources were identified with a contribution of one percent or more to the visibility impairment at Class I areas in other states. The list of sources identified by the KYDAQ's Q/d times RTMax analysis for given Class I areas are available in Appendix H.

Cost of Compliance

VISTAS contracted with Alpine Geophysics to evaluate control options and costs for sources within the AoI for the Class I areas of concern. Alpine used EPA's AirControlNet software to evaluate control options and costs for controls. The SO2 control suggested by the VISTAS control cost spreadsheet for Century Aluminum is a sulfuric acid plant at a cost of $14,207, $23,020, and $43,281 per ton of SO2 removed for potlines 1-4, potline 5, and the anode baking furnace respectively (See the VISTAS control cost spreadsheet for Century Aluminum in Appendix H). Therefore, since the cost of compliance for the control option ranges from 7 to 22 times greater than the cost-effectiveness threshold, the KYDAQ concludes that there are no cost-effective controls available for these Century Aluminum units at this time within the cost threshold established for this reasonable progress assessment.

Time Necessary for Compliance, Energy and Non-Air Impacts, and Remaining Useful Life

The three remaining statutory factors: 1) time necessary for compliance, 2) the energy and non-air quality environmental impacts of compliance, and 3) the remaining useful life of the emissions unit, while required to be considered, were deemed not applicable, since there were no cost-effective controls to evaluate.

7.9 What Additional Emissions Controls Were Considered as part of the Long-Term Strategy for Visibility Improvement by 2018?

Section 308(d)(3)(v) of the regional haze rule lists several factors that must be addressed in each SIP. These factors include the role of fire at Class I areas and status of state planning for smoke management, the role of dust and fine soil at Class I areas and status of state plans to mitigate emissions from construction activities, and the role of NH3 and potential benefits if emissions from agricultural sources were mitigated.

As discussed in Section 2.4 and demonstrated in Figures 2.4-1 and 2.4-2, elemental carbon (sources include agriculture, prescribed wildland fires, and wildfires) is a relatively minor contributor to visibility impairment at the Class I area in Kentucky. However, KYDAQ has an open burning regulation, 401 KAR 63:005, that establishes requirements for the control of open burning in Kentucky. The KYDAQ believes that 401 KAR 63:005, which is already incorporated into Kentucky's SIP, provides additional support to aid the Commonwealth with meeting its reasonable progress goals (RPGs) for this first planning period. A copy of KYDAQ's open burning regulation can be obtained at www.lrc.ky.gov. The exact benefits from the reduction in open burning emissions can not be quantified at this time and will not be included in Final VISTAS modeling.

Also as discussed in Section 2.4 and demonstrated in Figures 2.4-1 and 2.4-2, fine soils are a relatively minor contributor to visibility impairment at the Class I areas in Kentucky. Nevertheless, in regard to construction activities, KYDAQ has a fugitive emissions regulation, 401 KAR 63:010. Fugitive emissions, that provides for the control of fugitive emissions in Kentucky**.** The KYDAQ believes that 401 KAR 63:010, which is already incorporated into Kentucky's SIP, provides additional support to aid the Commonwealth with meeting its RPGs for this first planning period. A copy of KYDAQ's fugitive dust regulation can be obtained at www.lrc.ky.gov.

In regard to agricultural ammonia, Kentucky, per its CMAQ regional haze modeling with VISTAS, is focused on obtaining additional SO2 emissions reductions to address CAIR, BART, and consent decrees in Kentucky. The reduction in large amounts of SO2 emissions will lessen the formation of *Ammonium sulfate*, $(NH_4)_2SO_4$ emissions.

Additional Kentucky EGU controls for CAIR per IPM, consent decrees, and BART that can be quantified have been included by VISTAS in a final modeling run to address the cumulative benefits from the emission controls discussed in Section 7.2.1, any controls resulting from BART determinations within the VISTAS states and any other controls resulting from the states within VISTAS to address reasonable progress that can be quantified. If the final modeling run and analyses are completed within a reasonable period of time prior to the final Regional Haze SIP submittal on December 17, 2007, the KYDAQ would consider incorporating these findings in the final SIP, including revising reasonable progress goals if needed. If the modeling runs and analyses are not completed in time, the KYDAQ will review the information as it becomes available and determine if a SIP revision is necessary. Furthermore, if the addition of some additional controls or changes in a final VISTAS model run does not significantly change the current VISTAS regional haze modeling results for Kentucky, as presented in Section 8, then it is not likely that KYDAQ will modify its regional haze SIP for this reason.

8.0 REASONABLE PROGRESS GOALS

The regional haze rule at 40 CFR 51.308(d)(1) requires a State to establish reasonable progress goals for each Class I area within the state (expressed in deciviews) that provide for reasonable progress towards achieving natural visibility conditions by 2064. In addition, the USEPA released guidance on June 7, 2007 to use in setting reasonable progress goals. The goals must provide improvement in visibility for the most impaired days, and ensure no degradation in visibility for the least impaired days over the SIP period.

In accordance with the requirements of 40 CFR 51.308(d)(1), this Regional Haze SIP establishes reasonable progress goals for the Class I area in Kentucky. The KYDAQ compared baseline visibility conditions to natural visibility conditions in the Class I area to determine the uniform rate of visibility improvement (in deciviews) that would need to be maintained during each implementation period in order to attain natural visibility conditions by 2064.

Through the VISTAS modeling, the KYDAQ has estimated the expected visibility improvements resulting from existing federal and state regulations. As alluded to earlier, VISTAS in December 2007 and also into 2008 was in the process of modeling additional control measures found to be reasonable to implement in this review period by the VISTAS states, as well as the results of VISTAS states' BART determinations. The KYDAQ will not include the results of this final modeling run in its final SIP submittal due to timing and since the results provide reasonable progress goals that are very similar and as favorable to the ones presented in this section. The VISTAS baseline modeling has already demonstrated that the 2018 base control scenario provides for an improvement in visibility better than the uniform rate of progress for Kentucky's Class I area for the most impaired days over the period of the implementation plan and ensures no degradation in visibility for the least impaired days over the same period.

Table 8.0-1 contains the reasonable progress goals for this planning period for Kentucky's Class I area. For the 20% worst days, the reasonable progress goal for the Class I area provides for greater visibility improvement by 2018 than the area's uniform rate of progress. For the 20% best days, the reasonable progress goal for the Class I area indicates an improvement of visibility by 2018 than current best day conditions. These goals are based on the modeling results discussed in Section 7.2.4. The model performance for the 20% best days is not as good as for the 20% worst days because the model has greater difficulty accurately projecting small concentrations. On the 20% best days, the model does not meet VISTAS model performance goals or criteria for sulfate, nitrate, and coarse mass (under predicted) and soil (over predicted), however, the organic carbon and elemental carbon do meet performance goals on the 20% best days. Given the larger percent errors of the fractional bias on the 20% best days, the KYDAQ has less confidence in the absolute values projected for these reasonable progress goals, however, the KYDAQ does expect that visibility on these days will be better than the current conditions 20% best days.

Table 8.0-1. Kentucky 2018 Reasonable Progress Goals (in decviews)

Class I Area	Baseline Visibility for 20% Worst Days (dv)	Uniform Rate of Progress for 20% Worst Days (dv)	Reasonable Progress Goal Modeled for 20% Worst Days (Improvement) (dv)	Baseline Visibility for 20% Best Days (dv)	Uniform Rate of Progress for 20% Best Days (dv)	Reasonable Progress Goal Modeled for 20% Best Days (Improvement) (dv)
Mammoth Cave National Park, KY	31.37	26.64 (4.73)	25.56 (5.81)	16.51	16.51 (0.00)	15.57 (0.94)

9.0 MONITORING STRATEGY

The State Implementation Plan is to be accompanied by a strategy for monitoring regional haze visibility impairment. Specifically, the Regional Haze Rule states at 40 CFR 51.308(d)(4):

> "(4) *Monitoring strategy and other implementation plan requirements.* The State must submit with the implementation plan a monitoring strategy for measuring, characterizing, and reporting of regional haze visibility impairment that is representative of all mandatory Class I Federal areas within the State. This monitoring strategy must be coordinated with the monitoring strategy required in §51.305 for reasonably attributable visibility impairment. Compliance with this requirement may be met through participation in the IMPROVE network. The implementation plan must also provide for the following:
>
> > (i) The establishment of any additional monitoring sites or equipment needed to assess whether reasonable progress goals to address regional haze for all mandatory Class I Federal areas within the State are being achieved.
> >
> > (ii)-(vi) [Other implementation plan requirements that pertain to reporting and use of monitoring data and an emission inventory.]"

Such monitoring is intended to provide the data needed to satisfy four objectives:

1. Track the expected visibility improvements resulting from emissions reductions identified in this SIP.
2. Better understand the atmospheric processes of importance to haze.
3. Identify chemical species in the ambient particulate matter and relate them to emissions from sources.
4. Evaluate regional air quality models for haze and construct relative response factors (RRFs) for using those models.

The primary monitoring network for regional haze, both nationwide and in Kentucky, is the IMPROVE network. Given that IMPROVE monitoring data from 2000-2004 serve as the baseline for the regional haze program, the future regional haze monitoring strategy must necessarily be based on, or directly comparable to, IMPROVE. The IMPROVE measurements provide the only long-term record available for tracking visibility improvement or degradation and therefore Kentucky intends to rely on the IMPROVE network for complying with the regional haze monitoring requirement in the Regional Haze Rule.

There is currently one IMPROVE site in Kentucky's Mammoth Cave National Park as provided in Table 9.0-1.

Class I Area	**IMPROVE Site Designation**
Mammoth Cave National Park	MACA1 (KY)

Table 9.0-1. Kentucky Class I Area and Representative IMPROVE Monitor.

In addition to the IMPROVE measurements, some ongoing long-term limited monitoring supported by Federal Land Managers provides additional insight into progress toward regional haze goals. Kentucky benefits from the data from these measurements, but is not responsible for the funding decisions to maintain these measurements into the future. Such measurements include:

- Web cameras operated by the National Park Service in Mammoth Cave National Park

KYDAQ and the local air agencies in the State operate a comprehensive PM2.5 network of the filter based Federal reference method monitors, continuous mass monitors (TEOMs), and filter based speciated monitors. A map of the various locations around the State is included in Figure 9.0-1. These PM2.5 measurements help the KYDAQ characterize air pollution levels in areas across the state, and therefore aid in the analysis of visibility improvement in and near the Class I areas.

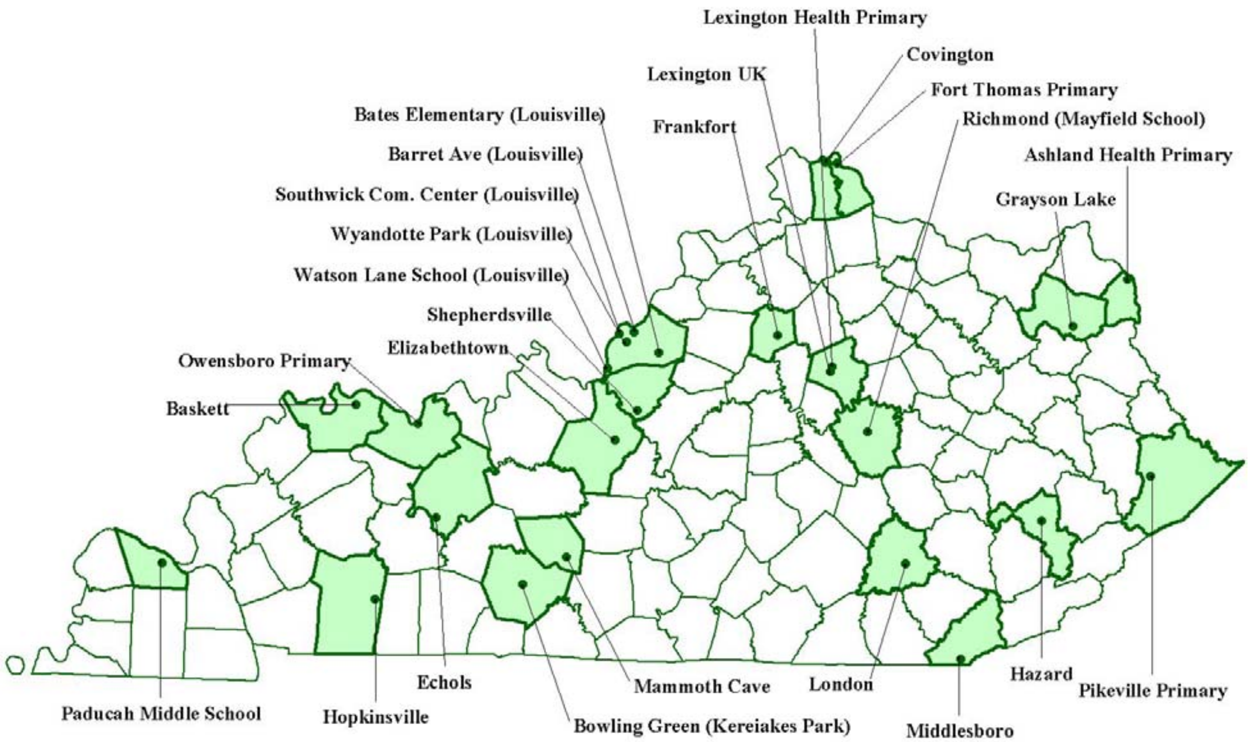


Figure 9.0-1 PM2.5 Monitoring Network in Kentucky.

The IMPROVE measurements are central to Kentucky's regional haze monitoring strategy, and it is difficult to visualize how the objectives listed above could be met without the monitoring provided by IMPROVE. Any reduction in the scope of the IMPROVE network in Kentucky would jeopardize the State's ability to demonstrate reasonable progress toward visibility improvement in some of its Class I areas. In particular, Kentucky's regional haze strategy relies on emission reductions that will result from the CAIR, which occur on different time scales and will most likely not be spatially uniform. Monitoring at every Class I area is important to document the different air quality responses to the emissions reductions.

Because each of the current IMPROVE monitor in Mammoth Cave represents a different airshed, reduction of the IMPROVE network by shutting down one of these monitoring sites impedes tracking progress at reducing haze at the affected Class I area. In the event this occurs, Kentucky, in consultation with the USEPA and relevant Federal Land Managers, will develop an alternative approach for meeting the tracking goal, perhaps by seeking contingency funding to carry out limited monitoring or by relying on data from nearby urban monitoring sites to demonstrate trends in speciated $PM_{2.5}$ mass.

Data produced by the IMPROVE monitoring network will be used nearly continuously for preparing the 5-year progress reports and the 10-year SIP revisions, each of which relies on analysis of the preceding five years of data. Consequently, the monitoring data from the IMPROVE sites needs to be readily accessible and to be kept up to date. Presumably, IMPROVE will continue to process information from its own measurements at about the same pace and with the same attention to quality as it has shown in the recent past. The VIEWS web site has been maintained by VISTAS and the other Regional Planning Organizations to provide ready access to the IMPROVE data and data analysis tools. KYDAQ is encouraging VISTAS and the other RPOs to maintain VIEWS or a similar data management system to facilitate analysis of the IMPROVE data.

10.0 INTERSTATE CONSULTATION

The VISTAS states have jointly developed the technical analyses to define the visibility improvement by 2018 under existing federal and state regulations compared to the uniform rate of progress, SO2 Areas of Influence for each Class I area, and methods to prioritize contributions from individual sources within the Areas of Influence. The states collectively accept the conclusions of these analyses.

In December 2006, the VISTAS State Air Directors held their first formal consultation meeting to review the modeling results and the SO2 Areas of Influence analyses. The Air Directors agreed to look at reasonable control measures for sources on the lists for the SO2 Areas of Influence. Each state would consider sources within their state and would identify sources in neighboring states that they would like to have that neighboring state consider. States acknowledged that the review process would differ among states since some Class I areas are projected to see visibility improvements near the uniform rate of progress while most Class I areas are projected to have greater improvements than uniform rate of progress.

In May 2007, the VISTAS State Air Directors met for their second formal interstate consultation. States shared their lists of sources in their state and neighboring states for each Class I area. They also shared their criteria for listing sources and their plans for further interstate consultation. A summary of this meeting is included in Appendix J.

The KYDAQ has evaluated the impact of Kentucky sources on Class I areas in neighboring and other states and determined that there are no additional reasonable control measures that should be implemented to mitigate impacts in Class I areas in neighboring and other states since no Kentucky source was found to contribute one percent or more to visibility impairment for other states' Class I areas (See Appendix H for KYDAQ's Q/d times RTMax analysis that identified sources with one percent or more impact for given Class I areas). Analysis of impacts from Kentucky sources and their existing and expected controls are provided in Appendix H. As discussed in following text, Kentucky received MANE-VU state requests for support in assuring reasonable progress pursuant to certain Kentucky sources. Copies of MANE-VU letters to KYDAQ are available in Appendix J. KYDAQ's response to MANE-VU is reflected in its regional haze SIP. In addition, a letter from Tennessee which relates that it does not plan to ask Kentucky for additional emission reductions for this first cycle of the regional haze SIP process is provided in Appendix J.

The KYDAQ has evaluated the impact of sources in neighboring states and their impact on Mammoth Cave and determined that there are no additional reasonable control measures that should be implemented to mitigate impacts on Mammoth Cave at this time. The KYDAQ sent letters to the Midwest RPO state of Indiana, the Lake Michigan Air Directors Consortium (LADCO), and to the VISTAS state of Tennessee regarding sources outside of Kentucky that were determined to contribute one percent or higher to Kentucky's Class I area. Kentucky related in its letters that since the units identified are EGUs subject to CAIR and since Kentucky's Class I area is currently exceeding the uniform rate of progress, Kentucky would not be requesting additional emission reductions at this time. Copies of the consultation letters can be found in Appendix J.

In addition, KYDAQ did participate in regional haze consultation regarding CENRAP states of Missouri and Arkansas regarding their Central Class I areas. Copies of the consultation letters with Missouri and Arkansas and conference call minutes are included in Appendix J.

The MANE-VU states of Maine, New Jersey, New Hampshire, and Vermont sent letters to Kentucky in the spring of 2007 stating that based on 2002 emissions Kentucky contributed to visibility impairment to Class I areas in those states. MANE-VU states asked KYDAQ to participate in further consultation with these states, and a meeting was held in August 2007, in Atlanta, Georgia with VISTAS states.

The MANE-VU states identified 14 EGUs in Kentucky that they would like to see controlled to 90% efficiency. They also requested a control strategy to provide a 28% reduction in SO2 emissions from sources other than EGUs (i.e., Non-EGUs) that would be equivalent to their low sulfur fuel oil strategy. Of the 14 Kentucky EGUs identified by MANE-VU, 93% of those sources have existing SO2 controls or will have SO2 controls by 2015 or sooner. Kentucky EGU existing and expected controls are provided in detail in Appendix H. The KYDAQ believes that the significant Kentucky existing and expected EGU emission controls more than adequately addresses MANE-VU's EGU and Non-EGU emission control requests. The letters from MANE-VU states and the meeting notes are included in Appendix J.

11.0 COMPREHENSIVE PERIODIC IMPLEMENTATION PLAN REVISIONS

40 CFR section 51.308(f) requires the KYDAQ to revise its regional haze implementation plan and submit a plan revision to USEPA by July 31, 2018 and every ten years thereafter. In accordance with the requirements listed in Section 51.308(f) of the federal rule for regional haze, Kentucky commits to revising and submitting this regional haze implementation plan by July 31, 2018 and every ten years thereafter.

In addition, Section 51.308(g) requires periodic reports evaluating progress towards the reasonable progress goals established for each mandatory Class I area. In accordance with the requirements listed in Section 51.308(g) of the federal rule for regional haze, the KYDAQ commits to submitting a report on reasonable progress to USEPA every five years following the initial submittal of the SIP. The report will be in the form of a SIP revision. The reasonable progress report will evaluate the progress made towards the reasonable progress goal for the mandatory Class I area located within Kentucky and in each mandatory Class I area located outside Kentucky which may be affected by emissions from within Kentucky**.**

The requirements listed in 51.308(g) include the following:

1. Description of the status of implementation;
2. Summary of emission reductions achieved thus far, including especially the status of implementation of the CAIR compliance plans for EGUs compared to the control assumed in the modeling;
3. Assessment of changes in visibility conditions at each Class I area (current vs. baseline), expressed as 5-year averages of annual values for 20 percent best and worst days;
4. Analysis of emission changes over the 5-year period, identified by source or activity;
5. Analysis of any significant changes in or out of the State which have impeded progress;
6. Assessment of the sufficiency of the implementation plan to meet Reasonable progress goals (RPGs); and
7. Review and any modifications to our visibility monitoring plan.

All requirements listed in 51.308(g) shall be addressed in the SIP revision for reasonable progress. In particular, the KYDAQ recognizes that the 2018 projections of EGU controls from the IPM runs represent one solution to how the CAIR requirements will be met. By the time of the first periodic report, the KYDAQ anticipates that the actual compliance strategy for the various utility companies will be much more defined. An assessment of those actual compliance plans will be done for the first periodic report.

The KYDAQ believes that its New Source Review (NSR) regulation for nonattainment areas as well as its Prevention of Significant Deterioration (PSD) regulation for attainment areas will address emissions from new sources that may locate near a Class I area or increased emissions from major modifications to existing sources. In addition to the KYDAQ regulations that would govern these sources, consultation with the FLMs is also required for sources that are subject to KYDAQ's NSR/PSD regulations.

KYDAQ also plans for continued consultation with the FLMs throughout the implementation process, including discussion of the implementation process and the most recent IMPROVE monitoring and VIEWS data. Consultation between KYDAQ and the FLMs will include early involvement of FLMs in the periodic review process and FLMs will receive copies of the revised regional haze SIP for comment prior to finalization.

There are several technical improvements that are recommended in the emissions inventory and air quality models that are used to support regulatory decisions for regional haze. These improvements recommended, as funding is available, to support the next long term strategy. The following is an overall summary; Appendix K contains a fuller discussion of possible technical improvements.

First and foremost, continued improvements are needed in the integrated one-atmosphere air quality models that are used to project air quality responses to emissions reductions. As our understanding of partitioning between gaseous and aerosol phases improves, this understanding needs to be reflected in the models. Improvements can also be made in how the models handle individual pollutants. Sulfate performance for the CMAQ regional air quality model is good overall. However sulfate deposition is frequently overestimated in the models, particularly in the summer months. At the coastal sites, when winds are blowing from the Gulf of Mexico or Atlantic Ocean, CMAQ underestimates measured sulfate at the monitors. CMAQ's processes also should be reviewed for sulfate formation over water. Nitrate is overestimated by the model in the winter and underestimated in the summer, although summer monitored values of nitrate are very low. Additional improvements in seasonal allocation of ammonia emissions would improve model estimates of ammonium nitrate formation. Organic carbon is generally underestimated in the summer months. Improvements are needed in the characterization of both primary carbon emissions and formation of secondary organic carbon.

Other improvements needed include better tools for organic carbon source apportionment, and more consistent measurement techniques between rural and urban monitoring networks. To improve our understanding of the contribution of fire from natural forest fires, prescribed burning, land clearing, and agricultural burning, states need improved record keeping. Additional improvements to international emissions inventory are also needed, to improve our understanding of boundary conditions for our modeling domain and of the contributions from international emissions to pollutant concentrations at the VISTAS Class I areas.

12.0 DETERMINATION OF ADEQUACY OF THE EXISTING PLAN

Depending on the findings of the five-year progress report, KYDAQ commits to taking one of the actions listed in 40 CFR section 51.308(h). The findings of the five-year progress report will determine which action is appropriate and necessary.

List of Possible Actions – 40 CFR section 51.308(h)

1) KYDAQ may determine that the existing SIP requires no further substantive revision in order to achieve established goals. KYDAQ would then provide to the Administrator a negative declaration that further revision of the SIP is not needed at this time.
2) KYDAQ may determine that the existing SIP may be inadequate to ensure reasonable progress due to emissions from other states which participated in the regional planning process. KYDAQ would then provide notification to the Administrator and the states that participated in regional planning. KYDAQ collaborates with states through the regional planning process to address the SIP's deficiencies.
3) KYDAQ may determine that the current SIP may be inadequate to ensure reasonable progress due to emissions from another country. KYDAQ would then provide~~s~~ notification, along with available information, to the Administrator.
4) KYDAQ may determine that the existing SIP is inadequate to ensure reasonable progress due to emissions within the state. KYDAQ would then take action to revise its SIP to address the plan's deficiencies within one year.